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INDUSTRIAL COMBUSTIBLE GASES.*

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THIS paper is intended to present—with some general prefatory remarks—an outline of the qualities and origin, or method of production, of the most important gases used in the arts, etc. The subject is a wide one, and for at all detailed treatment of its various subdivisions a volume, or even volumes, would be required. This treatment must, therefore, be brief. It is made as non-technical as compatible with clear understanding. Sufficient figures and descriptions of apparatus are given, however, to illustrate the chief demands of the art and the methods of meeting them. The particular designs of apparatus that are used for the production of each of the various gases are exceedingly numerous, and the quality of gas yielded is apt to vary somewhat according to this particular design, or even its method of operation; the illustrations chosen will, however, pretty accurately represent the general subject.

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It is probable that nothing will be given which is new to those having even a fair acquaintance with the gas business. To others who are not thus familiar, however, it is hoped to present an outline of the general subject which, because of its brevity, scope, and simplicity of treatment, will be easily read and of interest.

The special merits of gaseous fuel, which indicate the advantages obtained by the gasification of solid—and to some extent even liquid—fuels, are the following. It is easily transportable and capable of subdivision and use in even the smallest quantity. It is quickly combustible, and its flame, and consequently heat of combustion, capable of concentration. Undesirable impurities, which are incapable of removal from the solid or liquid fuels, can be purified out from their cooled gases, which in many processes is of great importance. It is easily combustible without smoke production. It is also possible to form from a solid or liquid fuel a gas having a greater heat of combustion, and consequently higher flame temperature, than the solid or liquid elements from which it is produced; a very notable instance of this is acetylene (C_2H_2), hereafter referred to, whose combustion yields a much greater heat, and a correspondingly higher flame temperature, than is yielded by its constituents (C and H) when burned in their elementary, or uncombined, state.

The gasification of solid fuels in a central gas plant, and the distribution of the gas for divided uses, offer enormous advantage. In the case, for instance, of domestic appliances for burning solid fuels, the combustion of this fuel is, in general, imperfect, and probably exceedingly so; also, because of the slowness of putting solid fuel fires into and out of operation, and the difficulty of limiting combustion when heat is either not required or required only to small extent, produces a further very serious waste of fuel; in addition to this, the labor of handling the fuel and the ash and managing furnaces is great. On the other hand, in the central station gas works apparatus is operated continuously, and with maximum efficiency of heat consumption and minimum cost for labor; the gas is delivered to the consumer exactly when and in such quantity as he desires, and its consumption is begun and terminated instantaneously when required, its combustion is perfect, the heat is utilized with a maximum of efficiency, and the labor of controlling the gas-

consuming appliance is almost nothing. The rapid advancement of the use of gas for domestic fuel testifies to this, and it is a probability of the future that the domestic gas-heating appliance will displace the coal-burning appliance, except possibly in cases of very large scale fuel consumption.

PROPERTIES OF THE INDIVIDUAL GASES CONSTITUTING, IN MIXTURE, THE INDUSTRIAL COMBUSTIBLE GASES.

The following table and appended notes give the essential properties of the various elementary combustible gases which, mixed in various proportions with each other and with incombustible diluting gases, constitute the various industrial combustible gases. The list of hydrocarbon gases and vapors is not complete—the number existing being very large—but those given are the ones of practical importance.

TABLE I.

Gas	Symbol	Weight per cubic foot, lbs.	Heat of combustion B. T. U.'s.		Air required for combustion.	
			Per cubic foot.	Per pound.	Cubic foot of air. Per cubic foot.	Pounds of air. Per pound.
Carbon (to CO)	C	....	....	4350	....	5.771
Carbon (to CO_2)	C	....	....	14544	....	11.541
Carbonic oxide	CO	.07407	323	4368	2.393	2.471
Hydrogen	H_2	.00530	326	61523	2.393	34.624
Hydrocarbon gases.						
Methane	CH_4	.04234	1009	23838	9.570	17.312
Ethane	C_2H_6	.07940	1764	22226	16.748	16.156
Ethylene	C_2H_4	.07410	1588	21430	14.355	14.836
Acetylene	C_2H_2	.06880	1477	21465	11.963	13.313
Hydrocarbon vapors						
Benzene	C_6H_6	.20640	3807	18447	35.888	13.313
Toluene	C_7H_8	.24345	4552	18699	43.065	13.547
Xylene	C_8H_{10}	.28050	....	....	50.243	13.720
Naphthalene	$C_{10}H_8$	.33870	....	....	57.420	12.984

All weights per cubic foot are for the gases under 30 inches barometric pressure and at 60° F. temperature.

The product of perfect combustion of carbon is CO_2, and of hydrogen is H_2O vapor.

The weights per cubic foot of the products of combustion and their elements are as follows: CO_2, .1164 pound; H_2O

vapor, .0476 pound; nitrogen, .0743 pound; oxygen, .0846 pound.

Dry air weighs .07658 pound per cubic foot; it consists of 20.9 per cent. oxygen and 79.1 per cent. nitrogen by *volume*, and of 23.13 per cent oxygen and 76.87 per cent nitrogen by *weight*.

The following is a brief statement of some additional facts concerning the foregoing individual gases, and their origin or formation, which are of importance in connection with our subject.

The combustible elements in all these gases are, of course, only two—carbon and hydrogen—the only ones available and recognized in practice as fuels. Carbon exists in combustible gaseous form in the hydrocarbons and also in CO, the product of its incomplete combustion with oxygen. Hydrogen exists in the hydrocarbons, and is also obtained, for the production of gas, by the decomposition of water.

Hydrocarbons.

The hydrocarbons are of much importance. The luminosity of luminous gas flames is entirely due to them. Also, they contribute largely to the heating power of many gases; for instance (see analyses), ordinary carburetted water gas and coal gas derive more than one-half of their total heating power from them. They are, of course, the sole source of production of the pure oil gases.

The hydrocarbons are divided, it will be observed, into two groups—gases and vapors. The gases are not condensable at atmospheric pressure nor at any existing atmospheric temperature, and consequently each one is capable of being distributed and utilized, unmixed with other gases if desired, in the gaseous form. The vapors, however, at ordinary atmospheric temperatures have a pressure less—and, in the case of those of great molecular weight, very much less—than that of the atmosphere, and consequently would be condensed to the liquid form if subjected to atmospheric pressure; therefore, in order that they may be transported in their vaporous form they must be mixed with one or more of the permanent gases, which shall serve as a "carrier." It will be observed that the vapors have far the greatest weight of molecule and weight per cubic foot, their vapor pressure, which is a measure of their ability to retain the

vaporous form under pressure, in general decreasing as the weight of molecule increases. Both gases and vapors have, as shown by Table I, high heating power per cubic foot.

As to the natural sources and artificial methods of production of these hydrocarbon gases and vapors, the essential facts are these:

Certain of them are, or have been, formed by natural processes, and are thus available to us. The only instance of practical importance in connection with our subject, however, is natural gas, which is composed very largely, or almost entirely, of methane (CH_4).

Certain of them are capable of artificial production or manufacture. The number which can be formed on a laboratory scale is large, and with the rapid development of synthetic chemistry practical processes will probably increase. A number of them are known to be produced in very small percentage directly from their elements, carbon and hydrogen, by the contact of these elements at high temperatures, which occurs, for instance, in the destructive distillation of coal in the coal gas processes, and in the manufacture of producer gas and water gas. Also, there exist some patented processes for the production of methane (CH_4), on a commercial scale, from uncarburetted water gas, and by means of the catalytic action of nickel, etc., we are not aware that such artificial production of CH_4 has yet been commercially effected, however. The one practically important case of artificial production of these hydrocarbons is acetylene (C_2H_2).

The most important source of these hydrocarbon gases and vapors is their production, in the manufacture of artificial gas, from oil, the volatile portion of wood, and the volatile portion of bituminous coals, by the process of "destructive distillation." In this process the foregoing materials are subjected to the action of heat to either vaporize the liquid, in the case of oil, or volatilize the volatile portion of the material if a solid. If the materials are subjected to only a sufficient degree of heat to produce this vaporization, the distilled products will be, in great part, merely heavy vapors, and upon being subjected to atmospheric temperature and pressure will recondense to the liquid form, and they are, therefore, incapable of distribution as gas. These vapors are, therefore, after distillation subjected to a

still higher degree of heat. Under this treatment there is a chemical change produced. In this transformation there is, in general, a reduction of the molecular weight of the vapors, some free carbon being thrown down (lampblack or soot) and some free hydrogen liberated, and the resulting gas will be a mixture of free hydrogen, permanent hydrocarbon gases, and small percentages of various vapors which are carried by the permanent gases; this mixture is capable of distribution. If the degree of heat to which the original vapors are subjected in this process of destructive distillation were very high, they would be completely decomposed into their constituents, carbon and hydrogen; for the production of a gas of both good luminosity and good heating power, from oil or coal, the original distilled vapors are made to attain a temperature of about 1300° F. to 1400° F.

Carbon Monoxide.

When oxygen unites with carbon in combustion two products may, and in general will, be produced—carbon monoxide (CO) and carbon dioxide (CO_2). CO_2 is the product of complete combustion and is itself, of course, incombustible. Carbon monoxide is the product of incomplete or partial combustion, and is itself a combustible gas, as will be seen by the above table. The two reactions are as follows:

$$O_2 + C = CO_2$$
$$O_2 + 2C = 2CO$$

The relative proportions in which CO and CO_2 will be formed are dependent upon the pressure and temperature at which combustion takes place and the length of time of contact of the air, and gases formed with the carbon; since in general gas manufacturing operations the pressure is sensibly that of the atmosphere, the temperature and time of contact are the controlling conditions. The quantity of CO produced will increase, and the quantity of CO_2 produced will consequently decrease, as the temperature is increased or velocity of flow decreased. Special experiments show that with exceedingly slow rate of flow, and a fuel (carbon) temperature of about 1900° F., practically only CO is formed; the CO_2 in the gas being only about one-half of 1 per cent.; with dry carbon and dry air supplied at 60° F., however, the heat of formation of the CO will be suffi-

cient to produce an actual temperature of off-going gas of about 2250° F., and a somewhat higher maximum temperature of fuel. (For further remarks on practical conditions see *Producer Gas.*)

Hydrogen.

As stated above, in gas manufacture hydrogen is produced from the decomposition of hydrocarbons. Another source fully as important is the decomposition of water vapor by its contact with a hot "reducing" agent. In the manufacture of combustion gases this reducing agent is, very generally, incandescent carbon (coal or coke). The oxygen taken from the water vapor and uniting with the carbon may, as shown in the above case of carbon monoxide production, form either carbon monoxide or carbon dioxide. All reactions are shown by the following formulæ:

$$H_2O + C = CO + H_2$$
$$2H_2O + C = CO_2 + 2H_2$$

The percentage of the total steam supply which will be decomposed and the respective percentages of CO and CO_2 which will be formed are, as in the foregoing production of CO, dependent upon the pressure and the temperature at which the reaction takes place and the length of time of contact, the percentages of steam decomposed and of CO formed increasing with increasing temperature of reaction and time of contact.

In a quiescent state of steam and gas, or with so slow flow as to approximate this, special experiments show that a fuel bed temperature of 1900° F. is sufficient to decompose practically all the water vapor supplied and produce only the CO. In practical work the fuel bed is operated at a much higher temperature than this in order to permit the effecting of these chemical changes at the high velocities of steam and gas actually employed; also, in pure water gas manufacture (see "Water Gas" following) the heat necessary for these reactions must all be stored in the fire by preliminary heating. Owing to the velocity and gradual dilution of the steam, a very considerable percentage of it will remain undecomposed, and there will also be some CO_2 formed, even at the high temperatures employed in practical work.

It is scarcely necessary to call attention to the fact that,

since this decomposition of water vapor is the inverse of combustion of hydrogen, it is a heat-absorbing process. If, as is always the practical case, water *vapor* (steam) is supplied to the hot carbon, the heat required to liberate 1 pound of hydrogen (by decomposition of 9 pounds water vapor) will not be the 61,523 B.T.U.'s indicated by Table I, which figure includes the latent heat obtained in the condensation of the H_2O vapor to the liquid form; it will be only about 52,000 B.T.U.'s. From this figure and that for the heat of formation of CO in Table I, an easy calculation shows that (assuming only CO formed) for each 1 pound of water vapor actually decomposed, two-thirds of a pound of carbon is carried away from the fuel bed in the CO of the resulting gas. The decomposition of the 1 pound water vapor will absorb about 5780 B.T.U.'s, the combustion of the two-third pound carbon to CO will develop about 2900 B.T.U.'s, or there will be a net absorption, with consequent cooling effect, of about 2880 B.T.U.'s; to this cooling effect must be added the heat absorption necessary to raise the temperature of the total resulting gas (CO and H_2) and any undecomposed steam to the temperature of its discharge from the fire, which will vary somewhat according to method of operation.

VARIOUS INDUSTRIAL GASES: THEIR QUALITIES AND MATERIALS EMPLOYED FOR MANUFACTURE OF ARTIFICIAL GASES.

In the following are given tables of analyses, which, with their appended text, give the kinds and volume percentages of the various foregoing elementary gases which, in simple mixture, constitute various industrial gases, the properties,—illuminating power, calorific power, flame temperature, etc.,—of these industrial gases, and their suitability for various uses; also, in the case of artificial gases, the materials from which they are produced.

The gases are good representatives of the products formed by the various methods outlined in remarks under Table I—destructive distillation, imperfect combustion of carbon by air with the formation of CO, the decomposition of water vapor by carbon with liberation of free H_2 and formation of CO, and combinations of these methods.

Notes.—In the case of the fuel analyses, the "proximate" analysis is obtained by drying the sample to drive off moisture,

then distilling to drive off volatile matter, then burning off the fixed carbon, successive weighings giving the various constituents; this analysis gives no information as to the quality of

TABLE II.

TYPICAL GAS MAKING MATERIALS.

ANALYSIS NO.	1	2	3	4	5	6
	Peat.	Lignite.	Bituminous Coals.		Anthracite.	Oil.
Proximate analysis.						
Moisture	35.0	35.0	1.3	.7	3.0	....
Volatile matter	42.5	25.1	36.7	17.9	5.6	....
Fixed carbon	19.0	34.7	53.5	75.8	80.5	....
Ash	3.5	5.2	8.5	5.6	10.9	....
Sulphur	....	....	1.7	1.2	.83	....
Ultimate analysis.						
Carbon	53.0	69.5	77.6	84.	83.7	84.9
Hydrogen	6.0	5.0	5.0	3.6	1.8	13.5
Nitrogen	1.8	1.5	1.3	1.7	.7	.2
Sulphur	....	1.5	1.7	1.2	.9	Trace
Oxygen	34.0	17.0	5.7	3.8	1.7	1.4
Ash	5.2	5.5	8.5	5.7	11.2	....

TABLE III.

GASES PRODUCED BY DESTRUCTIVE DISTILLATION.

ANALYSIS NO.	7	8	9	10	11
	Peat gas.	Lignite gas.	Bituminous coal gas.	Oil	Gas.
Illuminants	6.0	3.0	3.8	.4	38.1
CO	17.0	18.2	8.7	5.0	.5
H_2	27.0	44.1	50.5	78.9	3.4
CH_4	19.0	15.4	28.2	11.0	57.7
C_2H_6	....	....	2.8	....	....
CO_2	27.0	13.0	2.1	1.1	....
O_2	1.0	1.3	.4	.6	....
N_2	3.0	5.0	3.5	3.0	.3
Candle power	....	....	13.0	none	60.
Calorific power B.T.U.'s	467.8	424.	610.	394.	1488.
Specific gravity	.826	.596	.428	.222	.881

TABLE IV.

VARIOUS GASES.

ANALYSIS NO.	12	13	14	15	16
	Water gas.		Producer gas.		
	Uncarburetted.	Carburetted.	Anthracite.	Bituminous.	Natural Gas.
Illuminants	....	10.7	....	....	.1
CO	43.5	33.4	25.0	22.0	.2
H_2	47.3	38.1	14.2	10.5	....
CH_4	.7	7.6	.5	2.6	97.1
C_2H_6	....	2.4	....	.6	....
CO_2	3.5	3.3	6.3	5.7	....
O_2	.6	.7	.1	.4	.5
N_2	4.4	3.8	53.9	58.2	2.1
Candle power	none	20.2	none	none	5.0
Calorific power B. T. U.'s	302.	602.	132.	132.	982.7
Specific gravity	.559	.676	.871	.889	.566

the volatile matter. The ultimate analysis gives accurately the chemical composition; the ultimate analysis is, of course, of a dry sample.

In the case of peat and lignite their respective proximate and ultimate analyses (Analyses 1 and 2) and the analyses of the gases yielded (Analyses 7 and 8) do not relate to identical samples of these materials, such simultaneous data not being readily accessible to the writer; they are all correct, actual analyses, however, and accurately represent the facts intended to be brought out; the sample of lignite yielding the ultimate analysis shown is of rather unusually good grade.

The bituminous coals (Analyses 3 and 4) will generally, on being heated and before giving off their volatile matter, "cake" or melt, and assume a plastic form.

Coke, which is now greatly replacing anthracite, has, in general, even more fixed carbon and less volatile matter than anthracite.

In the gas analyses, under "illuminants," are grouped several different hydrocarbons, chiefly ethylene (C_2H_4), which, as the name indicates, impart luminosity to the gas flame; this group will vary slightly, in different gases, in constituency and calorific power per cubic foot; this calorific power will generally be somewhere about 2250 B.T.U.'s per cubic foot.

The distillation gases shown, produced from peat and lignite, are not commonly manufactured; neither is the light oil gas (Analysis No. 10), this being a sample of a gas made for balloon inflation, and which was required to be very light; these analyses are introduced simply for illustration of principles elsewhere mentioned.

The following is a brief statement of the qualities necessary in gases for various uses, and the suitability of the respective foregoing gases for these uses.

Flame Temperature.

In cases where low temperature work is to be done, high flame temperature is, of course, not so essential to efficiency of utilization of heat. In other cases, however,—as, for instance, in the use of gas for illuminating by the Welsbach mantle, the melting of refractory metals, etc.,—where the effect desired is obtained only at a high temperature, a very hot flame, or products of combustion, is very necessary for efficiency in utilization of heat, since it is only the excess of temperature of the flame above the physically or chemically necessary point which

accomplishes any useful work. Recuperation, or heating of air and gas before combustion by the heat of the waste products of combustion, can in many cases be practised, and thereby increase the efficiency of a low flame temperature gas, but in many other cases, as in the use of gas for illumination or other purposes, where gas is divided and used in small individual quantities, it is impracticable; the gas and air supply must be cold, and consequently the gas must be capable of yielding high flame temperature under this condition.

If a flame be protected from any loss of heat by radiation or conduction the products must carry away all the heat generated, and consequently the quantity of heat generated divided by the quantity of heat necessary to raise the products of combustion one degree in temperature will give the rise of temperature; adding to this the temperature of the gas and air before combustion will give the final flame temperature. This flame temperature can be approximately calculated; it cannot be accurately calculated, however, for, although heats of combustion of elements and gases have been accurately experimentally determined, the heat required to raise the temperature of the products of combustion one degree ("specific heat") has not, though approximately correct information has been obtained.

Even if we possessed the correct foregoing data for the calculation of flame temperature, however, that which exists in practice would be less for the following reasons. There is unavoidable some loss of heat from a flame, while combustion is in progress, by radiation and conduction. It is impracticable to obtain the ideal proportions of air and gas in combustion. There is also undoubtedly delayed combustion; in very hot flames the temperature of dissociation of a portion of the products of combustion is reached, and the combustion will consequently not be completed until some heat is dissipated.

Below are given the flame temperatures of certain gases, some determined by direct experiment and others calculated. The following remarks are made concerning them.

The experimental figures are quoted from a very good authority who made these determinations. They were made by a method which avoided the necessity of introducing any pyrometric device into the flame, with consequent lowering of temperature. Although they are commented upon by another

authority as being possibly somewhat high, they probably represent nearly the correct facts. As somewhat of a check upon them, it may be remarked that even with a small Bunsen burner of good design, consuming ordinary illuminating gas, it is possible to fuse platinum; as this temperature appears pretty positively determined to be over 3200° F., and as there is also in such case necessarily the loss of some heat from the flame by conduction, etc., it seems that in a large flame burned under the best conditions it should be possible to attain somewhere about the 3400° given by this experimenter.

The calculated temperatures have been computed by the writer; they are, as might be expected for reasons given in the foregoing, higher than the experimental figures. As to the important matter of specific heats to be used in making these calculations, from the writer's information there appears to be pretty close agreement among authorities in the case of nitrogen, carbon monoxide and carbon dioxide. In the case of water vapor we believe there is not such close agreement; the figures quoted seem to represent best information until at least recent date, though still more recent determinations seem to indicate that the quoted figures are too high. This last, if correct, would, of course, mean that the calculated temperatures for combustible containing hydrogen are too low. In connection with this, note that the calculated and experimental temperatures of hydrogen agree rather more nearly than is to be expected, though this may indicate either that the calculated temperature is too low, or else that the actual combustion of hydrogen is so efficient as to develop more nearly the theoretical temperature than in the case of carbon. The following are the specific heats assumed by the writer in making these calculations. (These specific heats are, of course, for constant pressure, which applies in the case of flames at atmospheric pressure; at constant volume,—as in the case of gas burned in a confined space,—the specific heat will be much lower, and consequently tend to give higher temperature of products of combustion);—

SPECIFIC HEATS AT VARIOUS TEMPERATURES FAHRENHEIT.

	2200°	2700°	3000°	3300°	3600°
Carbon monoxide (CO)	....	....	....	....	....
Nitrogen (N_2)	.2920	.3040	.3112	.3184	.3256
Carbon dioxide (CO_2)	....	.3235	.3382	.3529	.3676
Water vapor (H_2O)	....	.6660	.6924	.7188	.7452

FLAME TEMPERATURES.

Substance.	Burned with	Temperature ° F. Experimental.	Calculated.
Carbon to CO_2	Air	....	3540
Carbon to CO	Air	....	2260
CO to CO_2	Air	....	3670
Hydrogen	Air	3450	3510
Hydrogen	Oxygen	4400	....
Illuminating gas	Air	3400	....
Illuminating gas	Oxygen	4000	....
Acetylene	Air	4000	....
Acetylene	Oxygen	7200	....
Producer gas (Analysis No. 14)	Air	....	2735

In order that the foregoing may have some practical significance, the following few temperatures required in certain common high temperature industrial operations are quoted from various authorities;—

TEMPERATURE AT VARIOUS POINTS OF MANTLE OF WELSBACH LAMP.

	Degrees Fahrenheit.		
Ordinary lamp	2200	to	2650
"High pressure" (high gas consumption) lamp	2400	to	2850
Melting-point, of cast irons	2000	to	2500
" " wrought irons	2700	to	2900
" " steels	2200	to	2700
" " nickel		3000	
" " platinum		3227	
" " quartz		4000+	

The foregoing figures indicate that hydrogen, carbon monoxide and the hydrocarbons are all capable of giving very high flame temperatures, and that consequently the gases of Tables 3 and 4 (coal gas, carburetted and uncarburetted water gas, the oil gases, etc.) which are composed of them, and this with little dilution by incombustible gases, are all suitable for high temperature operations. Producer gas, on the other hand, owing to the presence of large quantities of incombustible nitrogen and carbon dioxide, gives far lower temperature.

A point in connection with this subject which is worthy of a moment's notice is the following. In Table I are given the actual heats of combustion of the various hydrocarbons, which hydrocarbons enter into the composition of some of the commercial gases given in Tables III and IV. If we calculate the heats of combustion of the elements (carbon and hydrogen) contained in these hydrocarbons, and compare them with the actual heats of combustion of the hydrocarbons themselves as given in Table

I, the two will be found to not agree, and this is for the following reasons. As is the case in all chemical combination, heat is evolved in the union of the carbon and hydrogen to produce these hydrocarbons, and, of course, the molecule will correspondingly resist decomposition into its elements, which decomposition must take place before combustion can occur; this heat absorption in decomposition will, therefore, affect the heat of combustion as compared with the calculated heat of combustion of the constituent carbon and hydrogen, as just stated. Methane (CH_4) has the highest heat of formation of the hydrocarbons which we are considering; its heat of combustion per cubic foot is (Table I) 1009 B.T.U.'s, whereas that of its constituent carbon and hydrogen is just about 100 B.T.U.'s greater; its flame temperature, therefore, must be somewhat lower than that of its elements. This heat of formation of hydrocarbons is in general low, however. Indeed, in a number it becomes apparently negative, which means that the work of decomposing these hydrocarbons for combustion is less than that which would be required in decomposing the elements (carbon and hydrogen) in their elementary condition. A very notable and practically important instance of this is acetylene (C_2H_2). The heat of combustion of one cubic foot of this gas is, from Table I, about 1477 B.T.U.'s, whereas the sum of the heats of combustion of the two constituents, carbon and hydrogen, is only 1250 B.T.U.'s; since the products of combustion from the elements and the gas are identical, the flame temperature of the gas must be much the higher. This fact accounts for the very high flame temperature of acetylene shown above, which contributes to its very high illuminating power, and renders the gas valuable for certain practical uses, such as the cutting of metals, etc. In connection with this peculiarity, it may be remarked that acetylene is, primarily, a high temperature product, the calcium carbide from which acetylene is generated, being itself formed only at the exceedingly high temperature of the electric arc, and there is, therefore, primarily the expenditure of very considerable energy to effect the ultimate forcing of carbon and hydrogen into this combination. Acetylene is the only hydrocarbon which exhibits this negative heat of formation, or endothermic property, in marked degree, and it is not a component of any

of the commercial gases shown in Tables III and IV in any measurable quantity.

Luminosity.

In former times light was obtained from only those gases giving luminous flames; although this method of obtaining light from gas is still employed, it becoming largely displaced by the use of the Welsbach mantle. As is stated in the remarks under Table I, the luminosity of gas flames is due to the presence in the gas of hydrocarbons, and these hydrocarbons are generally obtained only from high-grade bituminous coals and oil; consequently, for the furnishing of a luminous flame gas we are considerably restricted in our choice of materials and also methods of manufacture, which must necessarily mean increased cost of gas manufacture. With the Welsbach light, on the other hand, it is only required that the gas shall furnish a high temperature flame, and, as is shown in the above remarks on flame temperature, it is easy to manufacture from a very wide range of fuels gases (for instance, uncarburetted water gas, or a feebly luminous mixture of uncarburetted water gas and coal gas, or a low-grade coal gas) which shall have such abundantly high flame temperature. Hydrocarbons in a gas, as is above shown, do not necessarily increase the flame temperature, and those existing in the bulk of the industrial gases are of no more value for the production of heat or flame temperature than is carbon in the fixed form in all of the fuels from which can be readily produced the foregoing satisfactory gases. Furthermore, the quantity of heat required to furnish a given quantity of illumination is vastly less with the Welsbach mantle than with the luminous flame: one candle hour can be obtained with the Welsbach light with a consumption of from 36 B.T.U.'s with the ordinary low-pressure light to 20 B.T.U.'s with special, but now very commonly used, high-pressure lights; with the luminous flame, and using the good grade of coal gas shown in Analysis No. 9 of Table III, 235 B.T.U.'s will be required to furnish one candle hour. Incidentally, it may be mentioned that, while these hydrocarbons thus have in general practical cases no especial value as heating agents, many of them are of much value for chemical purposes and can, with profit, be extracted from gas and applied to these more valuable uses.

The foregoing facts are tending, and very properly, to lessen the legal requirements imposed with respect to luminous flame qualities of commercial gas, and this movement is certain to continue.

Calorific Power and Weight.

From the above it will be seen that the calorific power of a gas per cubic foot does not necessarily affect flame temperature (compare uncarburetted water gas, coal gas, and rich oil gas—all high flame temperature gases), and is, therefore, not of importance with respect to the heat efficiency of the gas when consumed. In the matter of distribution of gas, however, where expensive pipes and appurtenances and pumping machinery must be employed, this calorific power, and also the weight or specific gravity of the gas, have an influence which merits a moment's attention. Consider, for example, the transportation and distribution of a given quantity of energy per hour in two gases which could be produced from bituminous coal, one being producer gas, the other being a mixture of coal gas distilled from this coal, and the uncarburetted water gas which can be made from its residual coke. Approximately, these gases would have, respectively, calorific powers as 1 to 3 and specific gravities as 2 to 1. It is evident that the quantity to be transported of the first gas is at least three times that of the second, which will require pumping machinery of three times the capacity. Also (from the law of flow of gas through pipes), with identical pressure conditions in pipes, the first gas would, because of its three-fold volume and greater specific gravity, require pipe capacity (sectional area) about four times that required for the second gas, and would require mechanical work by pumping machinery more than three times that required for the second gas; or, with identical pipe capacity, the pressures for the first gas must be much higher, and the mechanical work of compression many times as great as for the second gas. In long-distance transmission of gas, where the initial pressure would be some, or many, atmospheres, this work of mechanical compression is an item of importance.

The foregoing striking example is chosen simply for illustration. Naturally, the manufacture of such a gas as this producer gas for long-distance distribution would not be attempted.

MANUFACTURE OF ARTIFICIAL GASES.

In the following is given a brief description of the methods of manufacture of the various artificial gases shown in Tables III and IV, and the general theoretical principles underlying these methods; also illustrations of representative forms of apparatus for the production of each of these gases.

Coal Gas.

This gas forms a very large portion of the entire commercial supply of combustible gases, especially those distributed for sale and use for illumination and other domestic purposes. "Coal gas" proper is the product of destructive distillation of bituminous coals which contain "volatile combustible," or matter—chiefly hydrocarbons—which can be driven off in the form of vapor, and permanent gas, by the simple application of heat. Other solid fuels shown—wood, peat, lignite—contain such volatile combustible in greater or less amount, and can be similarly treated, yielding a somewhat similar combustible gas, though, as shown by the analysis, the quality of gas produced is very dependent on the kind of material used, the "volatile combustible" differing greatly in quality in the various materials.

Let us briefly consider the materials, since they affect the quality of gas produced. In the formation by the processes of nature of high-grade coals from the original vegetable substances from which they are produced, there is a continual change of chemical constituency, as will be seen by comparing the analyses, beginning with peat and terminating with anthracite coal. The most important is the gradual elimination of oxygen, this existing in high percentage in peat, lignite, etc., and practically disappearing in anthracite coal. Also, hydrogen similarly decreases, though much more slowly; it remains in slightly diminished percentage in the hydrocarbons of the high volatile bituminous coals, but it is present in only small amount in anthracite coal.

The effect of the constituency of the material which is used upon the gas produced will be seen by comparison of the various gases,—those from peat, lignite, and bituminous coal (see Analyses 7, 8, and 9). The chief difference in quality of these gases is caused by the different quantities of the oxygen content of the respective materials. At the temperature of distillation and gasi-

fication this oxygen unites with part of the carbon in the fuel to form CO and CO_2, the latter being formed in very heavy quantity and passing off with the gas produced. This dilutes the combustible gases, and being itself incombustible it lowers the heating power and flame temperature of the gas; also, it very seriously injures the luminous qualities of the gas. The removal of the CO_2 by purification processes would be expensive; it may be removed by passing the gas through incandescent carbon, but this will result in a destruction of the hydrocarbons. Furthermore, it will be observed that the low-grade materials contain a large percentage of moisture, which will even remain in very considerable quantity after the most thorough drying practically possible; this is objectionable in the process of distillation. Also, the coke formed is generally in very poor quality. These facts prevent the use of these low-grade materials for coal gas production; the material generally employed is a high-grade, high volatile bituminous coal, such as shown in Analysis No. 3.

In the practical distillation or "carbonization" of gas coal this coal is enclosed, in masses ("charges") of very considerable volume, in some form of retort, and the exterior of the retort subjected to heat. To obtain rapid work and thus effect economy of carbonizing plant, the temperature of the exterior of the retort is made much higher than the temperature required to be attained by the material and the vapors for the distillation and gasification; the exterior of these retorts will ordinarily be from 2200° to 2600° F., or even slightly higher, whereas, as earlier stated, the best temperature to be attained by the distilled vapors for gasification is 1300° F., or slightly higher. It is evident that the heat necessary for the distillation of the interior of the "charge" must be transmitted through the exterior of the charge, and the gases evolved from the interior must, at least in part, and to an extent depending upon the form of retort, pass off through the exterior. Therefore, before the distillation in the interior can be completed, the exterior of the charge and the retort adjacent to it will have attained a very high temperature, and in the passage of the vapors and gas through this heated exterior there is some destruction of hydrocarbons, with consequent lowering of heating power and luminosity of the gas produced. Analysis No. 9 represents, however, the average quality of the gas produced during the distillation of an entire charge; the gas at the begin-

ning of the distillation period will be very much richer, and that at the end very much poorer, than this average. It is, furthermore, evident that even the lower grade coal shown in Analysis No. 4 may be capable of yielding, in the early portion of its carbonizing period, a gas of as good quality as that shown in Analysis No. 9; the average gas produced during the entire carbonizing period would, however, be of poorer quality.

Although not a subject for detailed consideration herein, a few words may be added concerning the other substances,—residuals or by-products and impurities,—formed in the manufacture of coal gas. The chief such substances and their derivation are the following:

The carbon of the bituminous coal which is not capable of being driven off in gaseous or vaporized form remains in the retort, after the distillation is completed, as coke. The proximate analysis of fuel (see Table II) is obtained by the distillation of only a small sample of coal, and, furthermore, this distillation is performed rapidly; these conditions cause the volatilization of a greater percentage of weight of the coal than is obtained in the slower distillation of very large masses of the coal in practical work. Hence, referring to Analysis No. 3 of Table II, although the proximate analysis indicates that the yield of coke should be 62 per cent. (fixed carbon plus ash) of the weight of the coal, the coke remaining in actual practical work would be about 68 per cent.; this is caused in greater part by the filtering out and decomposition of tars and heavy vapors in the large masses of coal treated, and at the temperatures employed, in practical work, the free carbon thus thrown down adding to the volume of the coke; also, the volatile matter will not be quite completely expelled from the coal in practice. The quality of the coke will vary according to the coal used and the method of carbonization. Even with coals of about the same grade in other respects there may be very considerable difference in coking quality, and differences in fineness or freshness from the mine also have an effect; the density and firmness of coke will in general increase with increase in internal pressure in the charge of coal and the length of time of carbonization.

Of the total nitrogen contained in the coal, as shown in the analysis, a portion will remain in the coke after distillation. The remainder, driven off with the gas, is in great part in the form

of ammonia (NH_3), either in the free condition or combined with sulphur compounds and CO_2. It is recovered by proper methods (the free NH_3 is easily recovered, for instance, by simple absorption in water, 1 volume of water at 60° F. absorbing about 780 volumes ammonia) and sold, being a very valuable by-product. A portion of the nitrogen coming off in the gas is in the uncombined form. A small further portion of the nitrogen unites with carbon to form cyanogen and its compounds; these compounds, which are used in, for instance, the manufacture of Prussian blue, are in large works recovered and form a by-product of some value.

Of the sulphur contained in the original coal a very considerable proportion remains in the coke. The remainder is driven off in the gas in the form of various compounds. The chief of these compounds are sulphuretted hydrogen (H_2S) and carbon bisulphide (CS_2). The H_2S is formed in vastly the greater amount, and, to prevent the contamination of the combustion products of the gas when burned, it must be removed from the gas before distribution and use; this is generally done by passing the crude gas through hydrated oxide of iron. The CS_2 is not thus easily removed; a small portion is removed in the foregoing passage through oxide, and, as the total quantity formed from a coal reasonably free from sulphur is small, the remainder is permitted to remain in the gas.

As has been before stated, a very considerable proportion of the hydrocarbon vapors distilled from the coal are of such heavy nature and of such slight degree of volatility that they cannot all be carried by the permanent gases. These heavy vapors are thrown down from the gas as soon as it cools to atmospheric temperature, after leaving the generating apparatus, and form tar.

The quantities of gas and the by-products, which will be obtained from one ton (2000 pounds) of coal of the quality shown in Analysis No. 3, Table II, will be, in good practice, as follows; though these individual figures will vary somewhat according to apparatus and other conditions:

Gas	10,500 cubic feet
Total coke	1300 to 1350 pounds
Ammonia	5 pounds
Tar	12 gallons
Candle power (flat flame)	13.

The quantity of fuel consumed in the carbonization of coal will, in present general coal gas works practice, be about 300 pounds per 2000 pounds of coal carbonized, depending on kind of apparatus and other conditions. The heat from this fuel will pass away from the apparatus in various ways, and the respective percentages dissipated through these various channels will evidently vary according to the form of apparatus and its operation. Some experiments have been made to ascertain the division of this total heat expended; one such experiment made, with much care, gave the following results. The form of apparatus used in this case was the horizontal retort setting described hereafter; it was provided with external recuperators, which probably somewhat increased the quantity of heat lost by radiation.

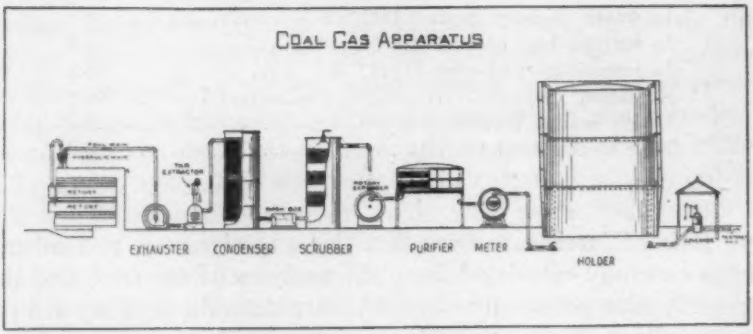
	Per cent.
In waste chimney gases (1112° F.)	25.2
In sensible heat of coal gas (1202° F.)	13.8
In sensible heat of coke (1742° F.)	18.5
Radiation, etc.	20.7
Latent heat of formation of gas, etc.	21.0
Heat of discarded ash	0.8
	100.0

It is of interest to note that this experimenter, and others, have carefully calculated from the analyses of the coal, and the gas and other compounds distilled therefrom, the quantity of heat required for the mere distillation of the volatile portion of the coal, and also the quantity of heat which is developed by internal reactions, during this distillation. While the different figures do not exactly agree, they all indicate that the net external supply of heat required is very small, or, in other words, the internal reactions generate quite, or very nearly, enough heat for this distillation. In the above itemized statement of heat losses is included the heat required for this distillation (latent heat of formation of gas, etc.), but this quantity of heat has already been charged into the gross quantity of heat supplied on which these percentages are based. The heat which requires to be supplied by the consumption of fuel is, therefore, apparently that represented by the above items of chimney gas waste, sensible heat of the offgoing coal gas, sensible heat of the hot coke as discharged from the retorts, radiation, and heat contained in the discarded ash.

The following illustrations and notes describe very good specimens of the various types of coal gas generating apparatus used in practice.

The illustration below represents in elementary, but quite complete, outline the apparatus employed for the distillation of coal gas from coal, and its subsequent treatment to prepare it for distribution. The raw coal is placed in the closed externally heated fireclay retorts, and the coal gas is distilled. The exhauster mechanically draws the gas from the retorts in order to preserve the pressure within the retorts at, or very close to, atmospheric pressure, and thus prevent possible leakage of gas. The tar extractor removes the heaviest tar and oil, which is precipitated immediately on the issuing of the gas from the retorts.

FIG. 1.

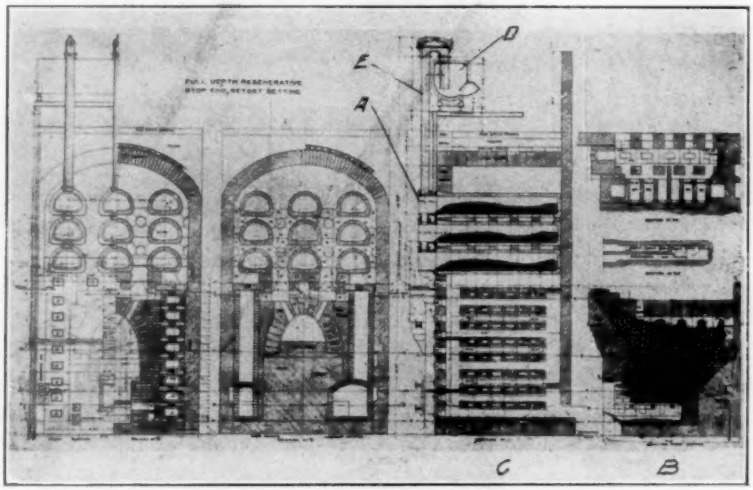


The condenser provides for further cooling and condensation of oils into suspended drops. The washbox removes these oils. The vertical scrubber and the rotary scrubber together effect the removal of ammonia from the gas; this is done by subjecting the gas to thorough and lengthy contact with water at proper temperature, which absorbs the ammonia. The purifier removes the sulphur impurities—chiefly sulphuretted hydrogen (H_2S)—from the gas; as has been before stated, the material commonly used for this purpose is hydrated oxide of iron, through layers of which the gas is slowly passed, the sulphur compounds being decomposed and the sulphur retained in the oxide. There are other chemical reactions, to more limited extent, in these various vessels. The gas is then measured in the meter, stored in the holder, and thereafter delivered through the governor, which

regulates pressure, to the street mains. In large works there is frequently very considerable auxiliary apparatus designed for the recovery of small percentages of by-products, such as cyanogen, and the manufacture of various individual products from the oils, tars, and ammonia; the apparatus shown, however, represents the essential processes of manufacture of the gas.

The further illustrations given will be only those of various forms of retorts for the distillation of the gas. It is these retorts and settings which chiefly vary in coal gas manufacture,

FIG. 2.



Stop-end horizontal coal gas retorts and setting.

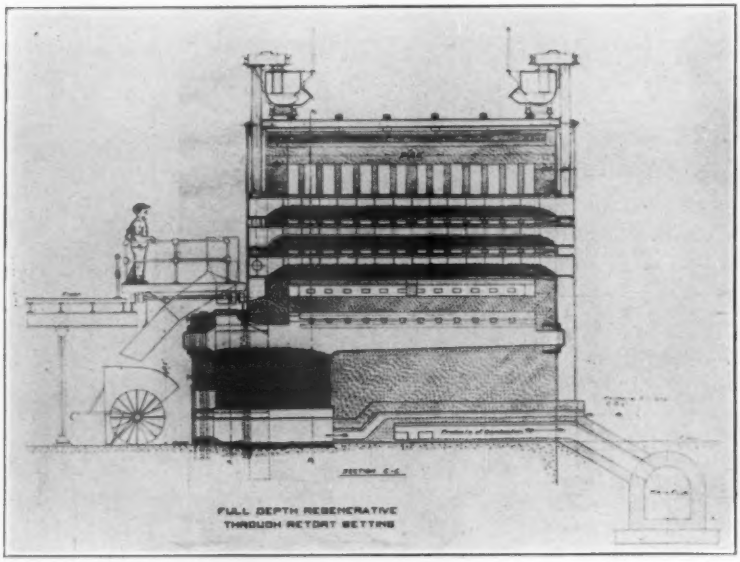
and which are, therefore, of special interest to us; the treatment of the gas after distillation will be practically the same, whatever the form of retorts employed.

The above illustration shows—though not all assembled as in actual construction (this assembling being shown in the next illustration)—the various parts of a setting of "stop-end" horizontal retorts such as are used in coal gas works. This form, though of very much cruder construction, is that which was used in the earliest manufacture of coal gas; in the improved form here shown and with greatly improved appurtenances, they are still in very extensive use.

The retorts (*A*) as shown are permanently closed at one end, and consequently the coal must be introduced into, and the coke withdrawn from, the same end of the retort; formerly this work was performed by hand, with shovel and rake, but modern plants are equipped with very complete and satisfactory machinery for the much cheaper mechanical execution of this work.

In the furnace, or "producer" (*B*), is consumed the solid fuel (coke) used for heating the retorts; for reasons given in later remarks on producer gas, a small quantity of steam, or

FIG. 3.



Through horizontal coal gas retorts and setting.

products of combustion, is generally admitted with the air supply to this fuel bed to prevent excessive temperature, and consequent trouble from clinker. Hot combustible producer gas issues from the top of this fuel bed, which is led in a number of divided streams into the arched space enclosing the retorts, is there mixed with a supply of secondary air, and burned for the heating of the retorts. Recuperators (*C*) are provided containing contiguous ducts for, respectively, the hot waste gases which have heated the retorts and the incoming air for combustion;

the air and hot waste gases have counterflow, and the sensible heat of the waste gases is, in great part, imparted to, and preheats, the air. In general present practice it is only the secondary air, or that which is to be supplied to the retort chamber for the combustion of the producer gas, which is heated, the preheating of the primary air for supply to the fuel bed having objectionable features.

The distilled gas, after issuing from the retorts, is carried into the "hydraulic main" (*D*) by the "standpipe" (*E*), the end of which pipe is lightly sealed in liquor in the hydraulic main; this prevents the return of gas from the gas mains back into the retort when the latter must be opened for charging or discharging.

The material employed for the construction of these retorts, their combustion chambers, recuperators, and setting, is fire-brick. Furthermore, to avoid melting or distortion of these parts under the high temperatures employed and the breakage of retorts, this fire-brick must be very refractory to heat, strong, and the most careful attention must be given to its proper burning before installation.

Fig. 3 shows a complete section of another form of horizontal retort and setting—the "through" retort. This form is coming into extensive modern use.

As is seen, this retort has a removable door at each end. This permits greater freedom in charging and discharging operations; instead of the coke being raked out of the same end of the retort at which is stationed the coke-removing device, a ram can be introduced into one end of the retort and the coke pushed out from the other end. It is also possible by this "through" construction of retort to charge the retort more fully with coal than is the case with the "stop-end" form; in the latter, space must be left for the insertion of the coke-drawing device, which is not necessary where the coke is pushed from the "through" retort. This more complete filling of the retort leaves less free space, and consequently hastens the exit of gas, which gives less liability to decomposition of hydrocarbons and also ammonia.

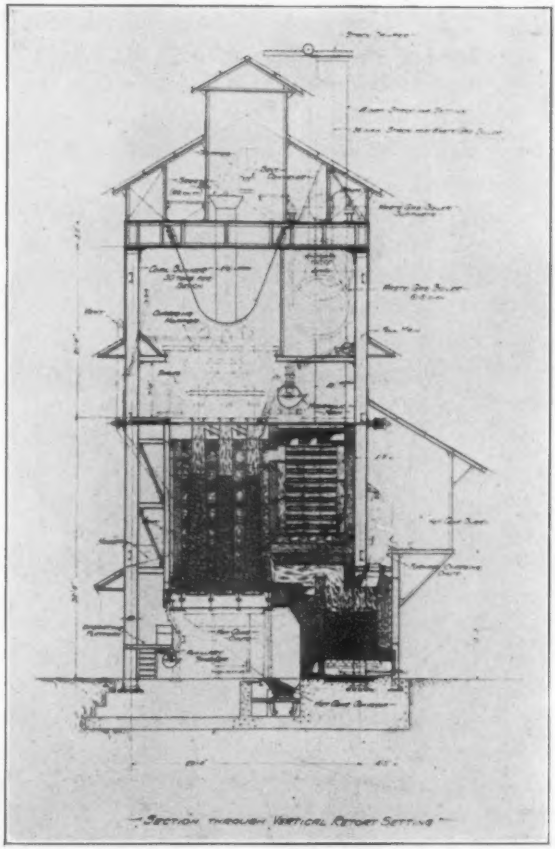
As shown, this form of retort is provided with a "standpipe" for the removal of gas at each end of the retort.

Observe the arrangement for dropping hot coke from the retort directly into the producer.

This setting is, of course, provided with recuperators for the preheating of air by the waste combustion gases, the same as shown in the above "stop-end" retort setting.

In modern construction these retorts are 21 feet long, contain a maximum charge of 1400 pounds of coal, and the length

FIG. 4.



Vertical retorts and setting. The United Gas Improvement Co.

of time for distillation or carbonizing of such charge is about seven hours.

The above illustration shows a setting of vertical retorts. Although retorts of such vertical form have for many years been employed for the distillation of an oil-containing rock, or

"shale," it is only within recent years that it has been employed for the distillation of coal and production of coal gas.

The advantage of this form of retort is that it permits charging of coal and discharging of coke by gravity, thus greatly lessening the labor cost for these operations which exists in horizontal form of retorts. Another advantage is that the plant occupies much less ground area for a given capacity than is the case with horizontals. Also, because of the greater depth of the charge of coal and the slower distillation, the coke produced is of excellent quality—dense, firm and suitable for metallurgical operations—and also contains less fine material, or "breeze," which is of much less value than the larger coke.

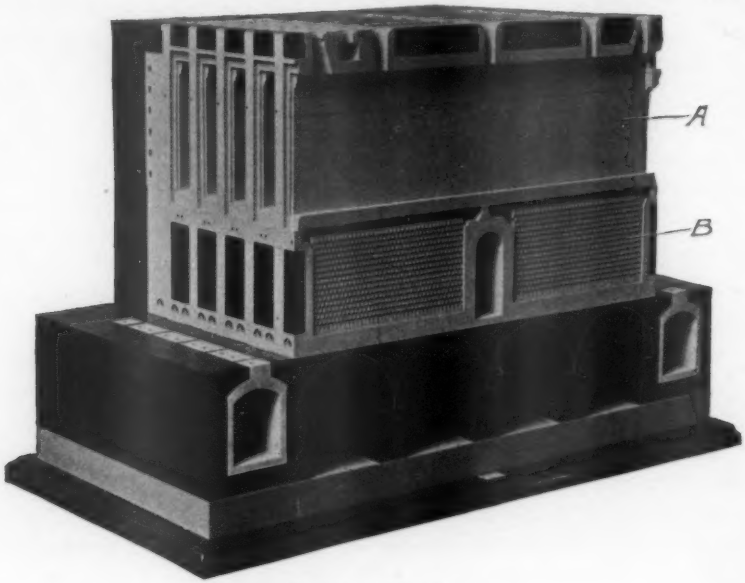
A noteworthy feature of this form of retort, as compared with the horizontal forms above shown, is that the entire cross-section of the retort is filled with coal. This leaves no, or very little, free space between the coal and sides of the retort. Consequently, gas is distilled at the surface of the coal and, in great part, flows inward toward the cooler interior of the charge, rises through it to the top of the retort, and is discharged. There is, therefore, less danger than in the horizontal form of decomposing of the hydrocarbons of the gas by contact with the very hot sides of the retort. Indeed, in this particular system an empty heated space, as shown, is left above the top of the charge of coal, through which the gas flows slowly and is subjected to additional heat for its more complete gasification.

The gravity charging and discharging feature of vertical retorts makes possible continuous charging and discharging, fresh coal being continuously fed to the top of the retort and coke continuously withdrawn from its bottom; such continuous retorts are now in practical use, though as yet to limited extent. The retort shown in our illustration, however, is not thus continuously acting, the entire retort being charged with coal, and emptied of coke, at fixed intervals.

In most recent construction these retorts are about 18 feet in length, and receive from 1000 to 1700 pounds of coal per charge. The time required for the distillation, or "carbonization," of this charge is from nine to twelve hours. The empty space above the coal is about 4 feet in length.

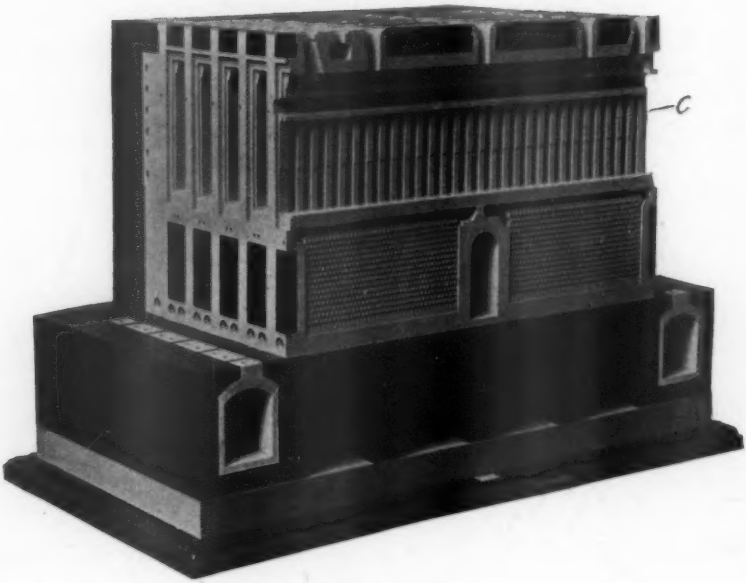
This form of retort furnishes not only, as above stated, an excellent grade of coke, but also an excellent quality and large quantity of gas.

FIG. 5.



Kopper coke oven.

FIG. 6.



Kopper coke oven.

The desire for coke-producing apparatus which should be more economical in respect to recovery of the by-products—gas, ammonia, tar, etc.—than the old bee-hive oven has led to the development and the very extensive modern use of the "by-product" coke oven. The gas produced from these ovens is becoming increasingly important for use in industrial purposes, and even in part for distribution, for general public use, by gas companies.

These ovens are designed primarily for the production of a superior grade of coke suitable for metallurgical purposes, etc. Consequently, the grade of coal chosen for use and the method of operation are generally such as to produce this best grade of coke; the gas is a by-product and is a secondary consideration. In many cases only the richest portion of the gas, which is that given off during the earlier portion of the carbonizing period, is sold for public supply, the remainder of the gas being used for the heating of the retorts. It is possible, however, with a good grade of coal and careful operation, to produce a total gas of very fair quality.

These ovens are generally installed in very large capacity, and require heavy machinery and appurtenances. They are not generally suitable for the use of moderate-sized gas works for the production of coal gas; furthermore, the quality of gas is not under such thorough control as in the above-described smaller forms of retort, and is in general somewhat inferior. For gas works use the above-described horizontal or vertical form of retort is preferable.

Figs. 5 and 6 represent models of one of the most modern by-product ovens. These models do not show the hydraulic mains, piping and machinery required for operation; they show very clearly, however, the construction of the retorts themselves, and as these are the things of chief interest to us these views are very satisfactory. An illustration of a complete oven, though of different design, is shown below.

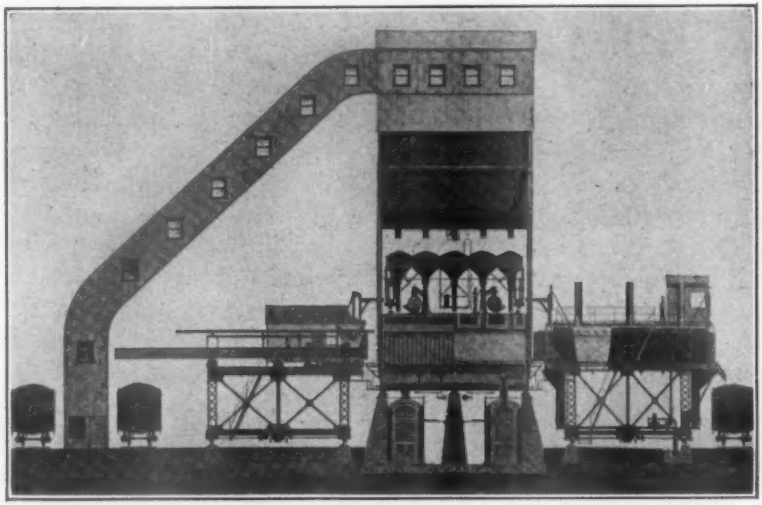
The first view shows a section through the retort proper (A) and through the fire-brick recuperators (B); the second view shows a section through the flues (C) contiguous to the walls of the retorts, which carry the hot gases which heat the retorts.

The fresh coal is charged, by gravity, through the openings shown at the top of the retorts. The coke remaining after

carbonization is pushed out horizontally by a powerful ram, there being sealed doors at the ends of the retort which are opened for this purpose.

In modern construction these retorts are 18½ to 21 inches (taper) wide, 11 feet high, and 39 feet long, and contain a charge of about 13 tons of coal; this large scale handling of materials is, of course, favorable to economy of labor. The length of time required for distilling or "carbonizing" a charge is with this size of retort from eighteen to thirty hours.

FIG. 7.

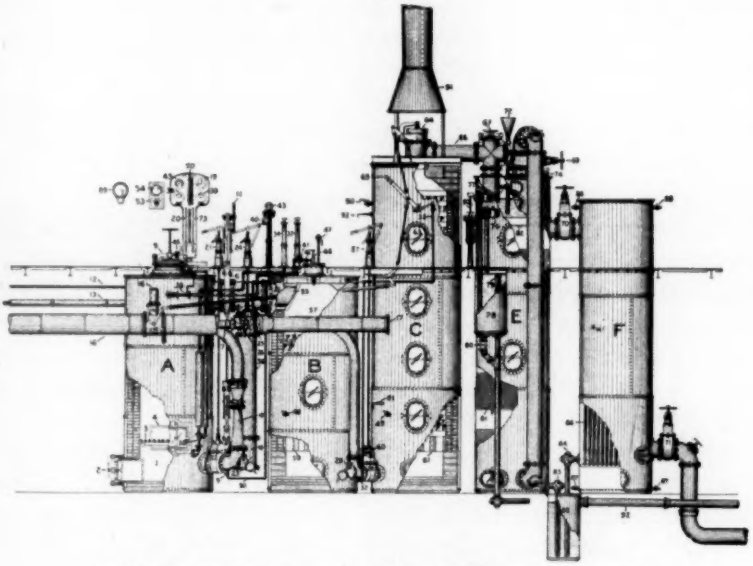


United-Otto system coke oven.

By-product oven retorts are generally provided with two gas exits and sets of piping; this permits the separate withdrawal, if desired, of the rich gas at the beginning of distillation and the poorer gas at the close of the distillation. As above stated, the poorer gas is frequently used for the heating of the retorts; where it is desired to otherwise dispose of this gas, however, these ovens are provided with producers for the combustion of solid fuel, as in the case of the above-described horizontal and vertical coal gas retorts, and the heating of the retorts is done by this producer gas.

Fig. 7 shows a complete installation of these coke ovens, though of somewhat different design from the models shown in the previous illustrations. Little explanation of this construction is required. On the left is the coal elevator delivering coal from the railway car to the storage bin above the retorts, whence it is fed into the charging hoppers and thence into the

FIG. 8.



Carburetted water gas apparatus. The United Gas Improvement Co.

retorts. Beneath the retorts are shown the checker-brick filled recuperators, which absorb the sensible heat of the waste products of combustion, and return this heat to the incoming air supply for combustion. On the left is seen the movable structure carrying the ram which pushes the coke from the retorts; this coke is received and cooled on the movable platform at the right, and thence discharged into cars.

Water Gas—Uncarburetted and Carburetted.

The above illustration shows a standard form of apparatus for the manufacture of carburetted luminous flame water gas. Since, in this process, one part of the operation is the production

of uncarburetted, or plain "blue," water gas, the production of both kinds can be considered together.

The generating apparatus proper consists of three steel shells, called, respectively, the generator (*A*), carburetter (*B*), and superheater (*C*), all lined with fire-brick, and the carburetter and superheater filled with fire-brick laid in "checker" form so as to be easily traversable by gases. The generator contains a bed of fuel—anthracite coal or coke—of, generally, from 5 to 7 feet in depth. (The succeeding vessels—scrubber and condenser—are simply for the cooling of the gas and the extraction of tars, etc.)

The operation of this apparatus is intermittent, or in cycles, consisting of two parts—first, the heating operation or "blow," and, second, the gas-making operation or "run." Briefly, the description of these operations is as follows:

In the blow, forced blast is supplied to the fuel bed for its heating. As stated in remarks under Table I (see also remarks hereafter on producer gas), the combustion gases issuing from the top of the fuel bed will contain both CO_2 and CO, the latter continually increasing in percentage as the temperature of the fuel bed rises during the blow. These combustion gases are led to the top of the second vessel, the carburetter, and here a secondary supply of air is admitted for the combustion of the CO. The combustion gases pass through the checker-brick in the carburetter and superheater, heating them, and the products of combustion are finally discharged at the outlet of the superheater. By proper adjustment of the time and intensity of blasting, the proper heating of the bed of fuel and the proper heating of the checker-brick are simultaneously completed without the loss of any unburned gases from the superheater outlet. When the heating operation is properly completed the temperature of the checker-brick will range from 2000° or 2200° F. at the top of the carburetter to about 1350° F. at the outlet of the superheater. Blast is then shut off, the apparatus is, by proper valves, sealed from the atmosphere, and the second part of the cycle—the production of gas or "run"—is begun.

In the run steam is admitted to the bottom of the generator fuel bed, rises through the bed, and, as stated in remarks under Table I, is decomposed by the incandescent fuel, forming a mixture consisting almost entirely of hydrogen and carbon

monoxide, called uncarburetted or "blue," water gas (see Analysis No. 12). This gas passes to the top of the carburetter, and there receives a stream of injected oil. The oil is vaporized by the hot checker-brick, its vapor mingles with the water gas, and the mixture passes through the succeeding checker-brick in the superheater. In this passage the oil vapors are, as explained in remarks under Table I on destructive distillation, chemically changed and converted into other hydrocarbons, chiefly those which are permanent gases. (Note that the foregoing temperature of 2200° at the top of the carburetter would be sufficient to largely decompose and destroy the oil were it not that the absorption of heat in the vaporization of the liquid oil prevents this.) The gas then passes from this generating apparatus into the subsequent apparatus for the removal of tars, purification, etc. This production of gas is, of course, a heat-absorbing process, this heat supply being required for the decomposition of the steam (see remarks on hydrogen under Table I), the vaporization and destructive distillation of the oil, and the heating of these gases to the temperature of discharge at the superheater outlet.

In making the "run" it is found advantageous to alternate the direction of flow of steam and gas through the fire, the steam being admitted for a portion of the time at the top of the fire, and during the remainder of the time at the bottom. This system gives much better control of the temperature of the fuel bed: the flow of hot gas down through the bottom of the fuel bed preheats the fuel, making it more readily ignited by the succeeding blast, which results in an economy of fuel. The construction of the apparatus shown is such as to permit of this, there being an exit for gas from both the bottom and the top of the generator.

Analysis No. 13 is typical of the finished carburetted water gas. The composition of the gas (percentage of hydrocarbons, etc.) and its calorific power and illuminating power can, of course, be varied by varying the quantity of oil used.

The kind of fuel required for this water gas manufacture is one—anthracite coal or coke—containing very little volatile matter. If much volatile matter be present, as in bituminous coal, the heat absorption required for the distillation of this volatile matter will tend to keep the temperature of the fuel below

the point at which combustion can take place and steam can be successfully decomposed; also, the efflux of gas formed from the volatile matter must tend to prevent the contact of steam with the fuel, thus further preventing the decomposition of the steam. Though bituminous coal has, to slight extent, been used in water gas generators, its conversion into coke, after being charged upon the fuel bed, must be completed before it will successfully effect the decomposition of steam; this slow process has prevented its successful use for water gas manufacture.

Producer Gas.

The use of this gas is so common and the theory of its production so simple that little explanation of the subject is necessary. There are, however, a few points worthy of brief attention.

As is stated in remarks under Table I, if air be supplied for the combustion of a bed of solid fuel, the products of combustion will generally contain both CO_2 and CO, the former decreasing and the latter increasing, in percentage with increase in temperature of the fuel bed. Starting with a moderately hot fuel bed and maintaining, for instance, a constant air supply, the temperature of the fuel will continually rise. As it does so, the percentage of CO formed increases, and, from the heats of formation of CO_2 and CO (see Table I), it is evident that the heat generated by the constant air supply will decrease until finally a state of equilibrium is reached, the sensible heat of the producer gas issuing from the fuel bed equalling (neglecting the incidental losses by heat radiation, etc.) the heat generated by the combustion in the fuel bed; this prevents any further rise of the fuel bed temperature. In the remarks on carbon monoxide under Table I it was stated that in the combustion of pure dry carbon with dry air, both supplied at 60° F., and with exceedingly slow flow of air and gas, giving time for complete chemical equilibrium, the temperature of gas and fuel bed will be about 2250° F., and practically no CO_2 will be formed, but only CO. In practical work the conditions and results will not be such; they are modified as follows. The rate of flow of air and gas must be quite rapid, and, with the large interstices and irregularities existing in the fuel bed, the gas and air will not come into such contact with the fuel that chemical equilibrium can become complete for the temperature, which will mean the formation of less

CO and more CO_2, and this will, in turn, mean higher temperature of both fuel bed and gas; also, there will be a slight heat-recuperating action of the fresh fuel as it heats and descends into the producer, this tending to increase the temperature in the hottest belt of the fuel bed. On the other hand, the fuel practically used will contain some mechanically-held moisture and some volatile matter, and the evaporation and distillation of these and the heating of their vapors will absorb heat; also, there is unavoidable loss of heat by radiation, etc.; also, ash exists and must be heated; these actions tend to lower the temperature of fuel and gas. With dry and good fuel the net effect of all the foregoing actions would be to produce a temperature in the hottest part of the fuel bed higher than the foregoing 2250° F. It is undesirable, however, that the fuel bed and gas shall attain so high a temperature for the following reasons; it will generally melt ash so as to form troublesome clinker in the fuel bed; also, if the use of the gas is such that it must be cooled and purified before burning, its high temperature means much more heat wasted, or recovered with added expense. Instead, therefore, of permitting so high a temperature of fuel bed and the carrying away of so much sensible heat in the issuing gas, a portion of this heat is utilized for the production of additional combustible gas; the method generally adopted is one of the following two:

1. Steam is admitted, mixed with the air supply, to the fuel bed and is decomposed, producing "blue" water gas mixed with the producer gas proper. The reactions, and the cooling effect upon the fuel bed and gas, are indicated in remarks on hydrogen under Table I.

2. Products of complete combustion of carbon (nitrogen and CO_2) are returned, mixed with the air supply, to the fuel bed. A portion of the CO_2 is decomposed by the hot fuel, forming CO, each one volume of CO_2 decomposed yielding two volumes of CO, which means that for each one pound of carbon contained in CO_2 which is actually decomposed by the fire two pounds of carbon (or an additional pound) will be carried away from the fuel bed. From Table I it will be seen that the decomposition of the CO_2 containing one pound of carbon will absorb 14,544 B.T.U.'s, while the formation of the resulting CO containing two pounds of carbon will evolve only 8700 B.T.U.'s; there is, therefore, a strong cooling action on the fire, which will be

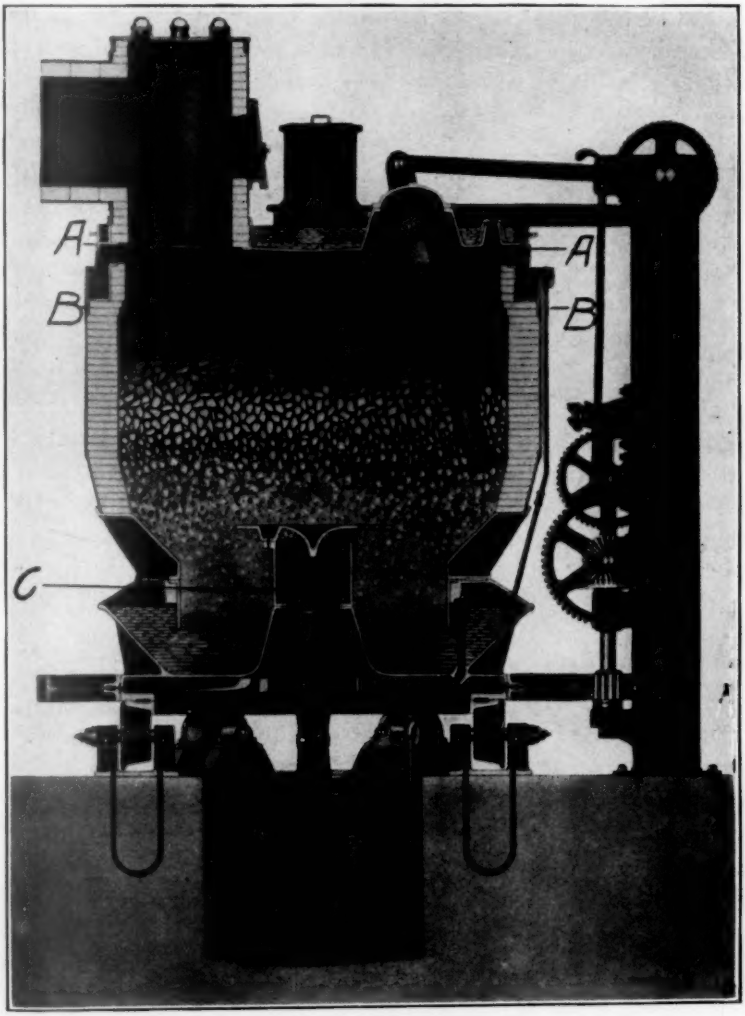
increased if, as is generally the case, the products of combustion returned to the fire are of a somewhat low temperature. This method has the superiority to the foregoing steam admission method that the products of combustion used can be those formed from the producer gas itself when burned in engines, furnaces, etc., and can thus be circulated indefinitely, whereas in the foregoing process of simple admission of steam to the fuel bed this steam must finally be discharged to the atmosphere (in waste products of combustion), and its sensible heat and latent heat of evaporation thus wasted. This process yields a producer gas which is considerably diluted, and which will have, when burned, from either a hot or cold condition, a lower flame temperature. This last fact is in some cases an advantage; for instance, in furnaces it yields a more uniform, even though lower, temperature, and thus avoids possible danger to brickwork, etc.

Because of its heavy dilution with incombustible nitrogen, cold producer gas, when burned, gives a lower flame temperature than coal gas or carburetted or uncarburetted water gas (see remarks on flame temperature); also, its flame is more easily extinguishable, or is more "tender"; also, because of its low calorific power and its heavy weight, it is more expensive to distribute. These facts cause its use to be generally confined to the locality of its generation, and it is, moreover, preferable, where its use will permit, both for heat economy and to permit of its giving a high flame temperature, that it be burned in its heated condition as it issues from the generating fuel bed; for such use as for gas engines, which is exceedingly extensive, it must, however, be used cold.

The fuels used for the manufacture of producer gas can be any of the solid fuels shown in Table II; large quantities of even lignite and peat are used in certain localities, though it is generally preferable to use a good grade of bituminous or anthracite coal. The foregoing fully explains the formation of gas where anthracite coal or coke is used. Where bituminous material is used the volatile combustible is driven off by the heat of the fire, and then the production of the producer gas proper from the resulting coke takes place. If the distilled hydrocarbons, etc., from the volatile combustible be removed (mixed with the producer gas proper) from the producer without excessive heating and

consequent decomposition, it will give a gas of materially greater heating power, of higher flame temperature, and which is capable,

FIG. 9.



Hughes producer.

because of the presence of the hydrocarbons, of being burned with a somewhat luminous flame of greater heat radiating power,

which is desirable in some furnace uses; also, such treatment of the distilled and volatile matter renders possible the recovery of tar and ammonia, which are protected from destruction by excessive heating. This object, if desired, is attained by the removal of the distilled gases from the producer close to the point where the coal is charged. If, however, the foregoing is not desired, the design of the producer is such that the hydrocarbons, etc., distilled from the volatile matter of the coal are caused to pass through the highly heated portion of the fuel bed, and are thus broken up by excessive heat more nearly into their elements, carbon and hydrogen; this converts the heavy vapors, which would otherwise be deposited as tar, in great part into fixed gases, and this greater freedom from tar and vapors is an advantage in some cases.

The above illustration represents a producer, suitable for the use of bituminous fuel, and of the form alluded to in the above general remarks, in which the hot producer gas proper passes off through the top of the fire, assisting in the distillation or carbonization of the bituminous fuel, and carrying this distilled gas directly from the producer without its further decomposition by heat.

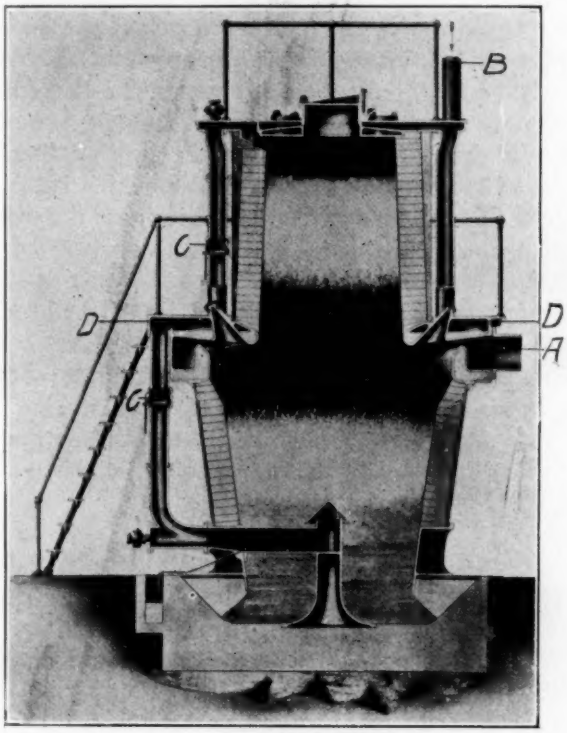
The cover (*AA*) of the producer is stationary. The body of the producer (*BB*), together with the fuel bed, is continuously rotated by the mechanism shown.

Bituminous fuel will generally, on being heated, melt or assume a plastic condition, which will interfere with the flow of the air and producer gas. In this producer provision is made for the continual breaking up of this plastic coal, and also the agitation of the general fuel bed and the working down of ash to the bottom. This is effected by means of the long arm shown, which projects down from the stationary cover into the fuel bed. This arm continually rocks back and forth, and as the body of the producer with the fuel bed is rotated there is thus produced a continual breaking up of the fuel.

The air and steam supply for the fuel bed are forced into its bottom through the vertical tuyere (*C*) shown. By means of the annular opening at the base of the producer, which contains a water seal for the prevention of communication with the atmosphere, the ash can be removed as desired.

Fig. 10 shows another form of producer suitable for the use of bituminous fuel. In this form, however, provision is made for the exposure of the gases distilled from the bituminous coal to a higher degree of heat, thus more thoroughly gasifying the heavy vapors and tars.

FIG. 10.



Westinghouse double zone producer.

The coal is charged upon the top of the fuel bed. The air supply for the combustion of the fuel is admitted in two parts, one over the top of the fuel bed and the other through the tuyere at its base. The air supplied to the top of the fuel bed produces a partial combustion suffcient to supply heat for the carbonization, or coking, of the coal, the coke thus formed then descending and its combustion being completed in the lower part of the producer. The producer gas with its contained vapors distilled

from the coal, from the top of the fire passes downward through the hot fuel and is removed through the pipe (*A*) at the middle of the height of the producer; the producer gas formed at the bottom of the fire rises and is discharged through this same pipe.

This producer is of the "suction" type, the producer gas being drawn off by an exhauster, and this suction draws in the air supply for combustion through the inlet (*B*). By means of the valves (*CC*) shown the total air supply for the producer is divided between the top and the base in any desired proportion.

The air supply, before its admission to the fuel bed, is passed over water which is used for cooling the producer head, and also over the water contained in the annular ring (*DD*) at the middle of the height of the producer, which latter is heated by the waste heat of the offgoing producer gas; the incoming air is thus charged with the water vapor necessary for supply to the fuel bed.

The water-sealed opening at the bottom of the producer permits of the removal of ash as desired.

The breaking up of the plastic fuel, working down of the fuel bed, etc., is, in this producer, effected by hand stoking. Stoking holes are provided for this purpose in the head of the producer and also at various points in the ring *DD*, which afford ready access to all points of the fuel bed.

Oil Gases.

The method most generally employed for the production of gas from oil is that of simple destructive distillation. In this process the oil is introduced into a closed vessel or retort and subjected to heat. A temperature of 700° or 800° F. will, in general, suffice for the practically complete vaporization of even heavy crude oils. As explained under Table I, however, these vapors would, if subjected to atmospheric pressure and temperature, immediately recondense to the liquid form. They are, therefore, subjected to a still higher heat to transform them into permanent gases. It is very generally desired to thus produce an oil gas which shall have both high heating power per cubic foot, and also high illuminating power. Analysis No. 11 represents such a pure oil gas, and this is also approximately the quality of oil gas which, mixed with uncarburetted, or "blue," water gas, is produced in the manufacture of illuminating carburetted water gas (see Analysis No. 13); the temperature which

the oil vapors must attain for such gasification is about 1300 to 1400° F. Under higher temperature of gasification than the foregoing there is further decomposition of these oil vapors into their constituents, free carbon and free hydrogen. Analysis No. 10 is that of an oil gas (intended for balloon inflation) formed by passing the oil vapors through a very hot bed of incandescent carbon (coke); it will be observed that there has taken place very great decomposition of the hydrocarbons into free carbon and hydrogen, the heavy vapors (illuminants) having been practically all destroyed, and the resulting gas being of very feeble luminosity. It is, in general, impossible to convert all of the oil into a mixture of permanent gases and vapors capable of transportation; a considerable portion of the vapors will be so heavy that they are incapable of carriage even when heavily diluted with permanent gases, and these vapors, mixed with free carbon, will be thrown down at the outlet from the generating apparatus in the form of tar.

A very considerable quantity of gas is also manufactured by mixing the oil vapors with steam in the foregoing destructive distillation process. At the temperature of gasification of these vapors, some of this steam will undergo decomposition by the portion of free carbon liberated from the oil gas, and there will thus be formed a mixture of oil gas and uncarburetted water gas.

With the kinds and uses of oil gas you are probably all pretty familiar. Large quantities of oil gas, of the quality represented by Analysis No. 11, are manufactured, compressed into portable reservoirs, and used for car, etc., lighting; this gas endures the high degree of compression employed in this use (15 atmospheres even) without serious loss of volume, heating power, or luminous power. Very considerable quantities of oil gas are manufactured, by the process indicated in the preceding paragraph, from the very heavy crude oils of the West, and used for public gas supply. Another interesting modern form of oil gas supply is to compress a gas of the general quality shown by Analysis No. 11 under a pressure of about 100 atmospheres, thereby liquefy roughly one-half of it, and deliver this liquid product in strong steel capsules for domestic use; on releasing this liquid, in whatever quantity is desired, from the capsule it is so volatile that it at once reassumes the gaseous form ready for use; there is thus obtained from the portable liquid gas of high heating power at any burner pressure desired.

Hallwachs-effect in Selenium. G. ZOLTÁN. (*Phys. Zeitschr.*, xiii, 454.)—Selenium was melted on a metallic disk and cooled rapidly. Some preparations were annealed at 217° C. to convert the selenium into the gray crystalline modification. The metallic plate was made the negative plate of an air condenser and was illuminated by a mercury lamp and charged by a water battery. The other plate of the air condenser was connected with a quadrant electrometer. The Hallwachs photoelectric current was measured by the angular speed of the electrometer needle, recorded on a chronograph. The results show, (1) in the case of crystalline selenium, that the photoelectric sensitiveness increases after the time of preparation, especially if kept in the light; the sensitiveness is increased by positive electrification at ordinary or low pressures, but reduced by negative electrification in the open air. (2) In the case of amorphous selenium, the sensitiveness is reduced by light and recovers in the dark. Negative electrification diminishes sensitiveness, while positive electrification increases it.

Efficiency of Illuminants. C. P. STEINMETZ. (*Electrician*, lxx, 346.)—It is pointed out that besides the efficiency of the illuminant such questions as the distribution of light, intrinsic brilliancy, and color are important. But practically any distribution curve can be obtained by suitable shades and reflectors, etc., although with some loss of light. A bad natural distribution curve is therefore a disadvantage, and so is a high intrinsic brilliancy. In correcting either of these defects a loss of from 10 to 30 per cent. may be incurred. Color has a direct influence on efficiency; bluish-green light is probably the most efficient radiation at low illuminations. A diagram is given showing the efficiency in candle-power per watt, plotted against the energy and consumption of various illuminants. The highest figure recorded for the titanium arc and yellow flame-arc is about 5 candle-power per watt.

High Tropical Winds. W. VAN BEMMELEN. (*Nature*, xc, 250.)—Observations of pilot balloons in Batavia confirm the existence of a high *westerly* wind above the trades and anti-trades, and immediately below the persistent easterly winds which are peculiar to the tropics, and which carried the dust from the Krakatoa eruption of 1883 many times round the earth at a level of about 30 kilometres. The order of the currents is as follows: (1) Shallow local breeze; (2) southeasterly trade wind to 3 kilometres; (3) northeasterly anti-trade to 17 kilometres; (4) upper southeasterly trade wind to 18 kilometres; (5) high westerly wind to 23 kilometres; (6) easterly Krakatoa wind to at least 30 kilometres. The velocities of the currents numbered (2), (3), (5), and (6) are about 5, 16, 12, and 35 metre-seconds respectively.

THE ELECTRICAL PROPULSION OF SHIPS.*

BY

W. L. R. EMMET, Sc.D.,

Consulting Engineer and Engineer of Lighting Department, General Electric Company.

MR. EGLIN has done me too much honor in introducing me as one of the foremost authorities on steam turbines in the world, because my function has been largely that of a developer of apparatus and enterprises, rather than that of an inventor, although incidentally I have done a certain amount of inventing.

Parsons is the great pioneer of the turbine, and De Laval is another who is entitled to great honor, and next to them comes Curtis, who after these other men had worked for a long time, for possibly eighteen years on the development of the turbine, it had only reached a small stage of advancement; that is, commercially. Mr. Curtis conceived an idea which was quite different in some respects from those previously designed, and which made the turbine somewhat more flexible as to speed, and introduced in it a number of practical characteristics which helped its advancement.

My part in connection with the turbine has been that of developing the Curtis turbine. Within two years after I undertook to work on the turbine, we had four or five times as many in operation as we had ever seen, and something like four times as large turbines, and that may have done something to stimulate the growth of the turbine and the advancement of it. That was the beginning of the turbine, but, so far as our interest is concerned, it began about 1901, and by 1903 we had turbines as large as 700 kilowatt capacity, stations as large as 7000 kilowatt capacity operating, and therefore the industry reached at a bound a high state of development, and then the reciprocating engine for making electricity went out of favor; this was probably within two years after we began building turbines and

* Presented at the joint meeting of the Electrical Section and the Philadelphia Section, American Institute of Electrical Engineers, held Thursday, January 9, 1913.

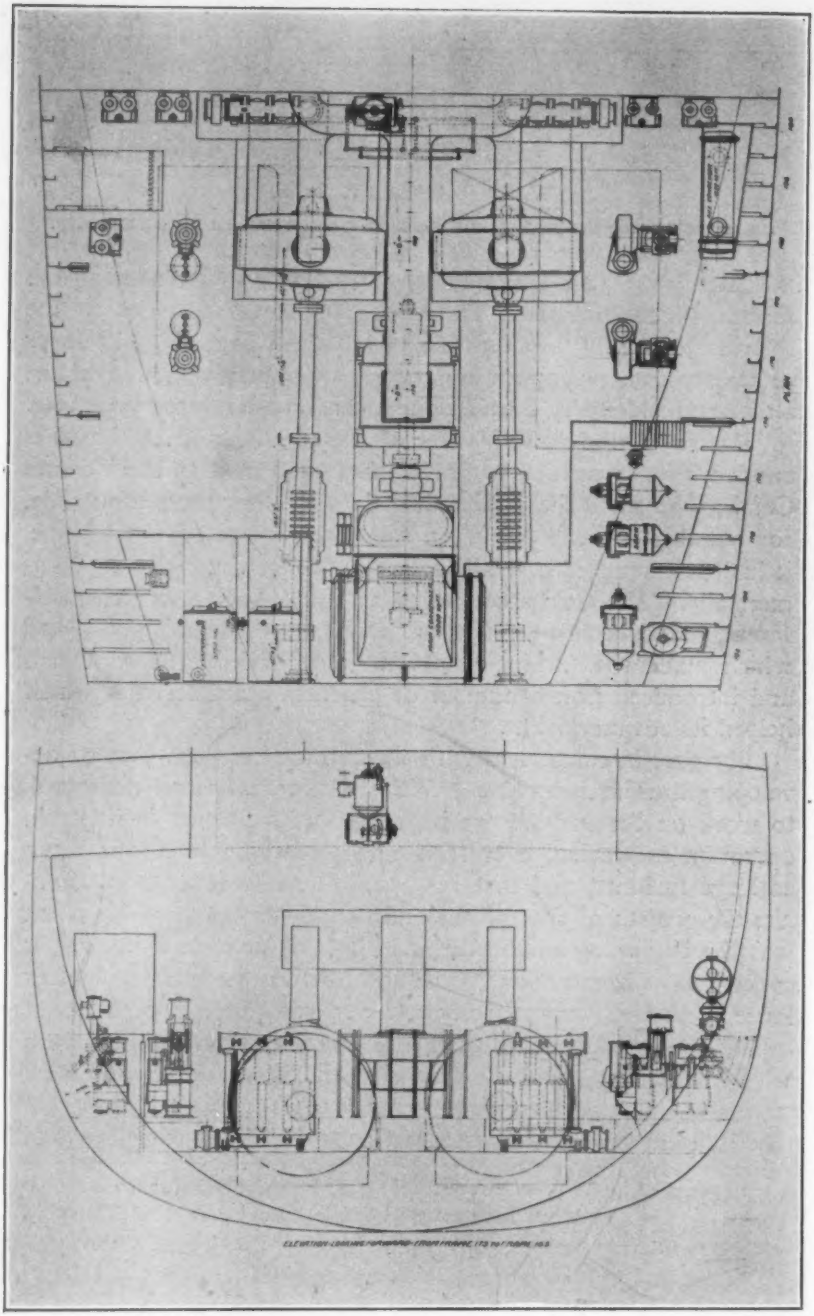


FIG. 1.

Arrangement of machinery, U. S. collier *Jupiter*. Electric drive.

FIG. 2.

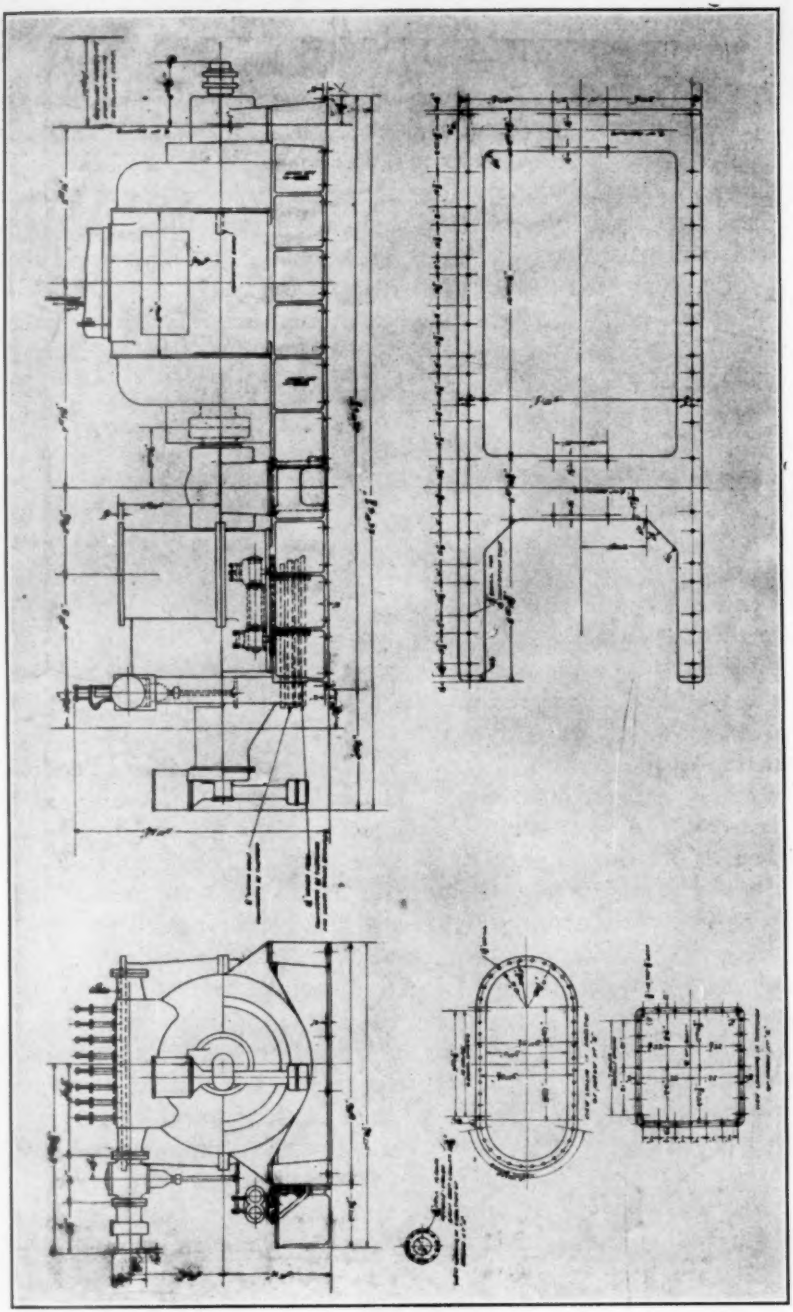


FIG. 2.

Outline of generating unit, U. S. collier *Jupiter*.

Arrangement of machinery, U. S. collier *Jupiter*. Electric drive.

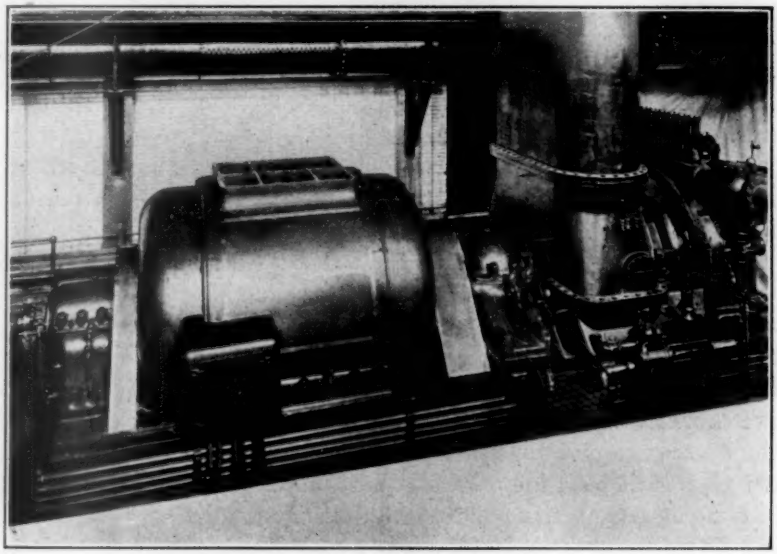
advocating turbine stations. I suppose in the earliest stage of the turbine for driving electrical machinery the idea was suggested of driving a ship by the turbine and motor. The idea has previously been discussed in connection with storage batteries. When Plante first demonstrated the principle it was said that ships would be driven across the ocean by storage batteries; there was some boat work done with storage batteries. You will remember that boats were propelled in that manner at the World's Fair, but the storage battery is too heavy and too inefficient, and its period of economical storage is too short to make anything like ship propulsion possible by its use, and all the methods of production of electricity known heretofore were such that they offered no inducement for driving ships by electricity.

Now, in what I am going to show you to-night and explain to you, there is very little of invention; it is simply an engineering evolution and development, at a certain stage of development which justifies certain proceedings and justifies the prediction of certain results. And the question remains as to whether those results are good enough to compete with other methods that apply to the propulsion of ships. The industry of propelling ships is one of the greatest engineering industries of the world. Many people do not realize the immense amount of power used in driving ships. It is safe to say that the power in the *Lusitania* would drive the electric railways of Philadelphia. I am not quite certain in that statement, but it is very nearly so; it would certainly do so for many hours of the day. That is only one ship of thousands.

The horsepower capacity of Parsons turbines which had gone into ships from 1905 to last year was reported at something like 9,000,000 horsepower, which is in the neighborhood of three times as much as the total output of turbines by the General Electric Company in ten years, and more than twice the total output of turbines in the United States; such a capacity has actually been put in ships in six or seven years to drive them with Parsons turbines. The only ships to which turbines have been applied are the very fastest vessels; turbines are suited to use in nothing but the fastest ships, and even there are relatively unsuitable. As time has gone on we see the turbine has been improved and put into positions of prominence. As a pro-

peller of ships where it may be driven at high speeds, at the time of its sudden rise to prominence it was a very noticeable piece of machinery, and its economies were simply an approximation of those which were supposed at that time were possible. When I advocated this tremendous plunge in turbines and took the responsibility of jeopardizing millions of dollars of my employer's money in going into this enterprise, I had no idea that the turbine was as much better than the engine as it has proved,

FIG. 3.



Generating unit, U. S. collier *Jupiter*.

but was confident that, being better than the engine in the beginning, the reason for its use would increase.

When we first began to build turbines, the speeds of them were relatively low, but they were high compared with reciprocating engines, but were low as compared with those which we can now build. The generators which were used to make electricity from the turbines were at that time very radical in the matter of speed, and they were a matter of terror to people who were going to use them. The centrifugal strains were great; but as time has gone on we have developed better methods, and,

while we at first feared to build a high-speed generator, we have for some time past had such success in building high-speed generators that the limit has been in the turbine. There have been certain limitations in the speed of the turbine which determined the capacity of a unit of a given speed. But very recently, since the publication of any of my papers on electrical propulsion of ships, this speed limit has been raised by the development of a means of designing a turbine which has enabled us to get the highest efficiency with very high speed, and this change has brought with it an added reason for advocating ship propulsion by electricity.

Now the net result of all this is that when we began to build turbines we could just beat the reciprocating engine that was then used for making electricity. Our machine was better and a little more efficient, but very slightly. Its increased efficiency was due almost entirely to the fact that a turbine is a machine in which you can use the full expansion of steam, whereas a reciprocating engine is a machine in which you cannot use the expansion of steam. The volume of steam with the vacuum which is customary in power stations is something like 200 times as great as the volume of steam which issues from a steam boiler. The curve of the expansion of steam is, as you know, a hyperbolic curve, and the areas of these long ranges of expansion are enormous. A reciprocating engine working condensing, with the best vacuum obtainable, is only about 25 per cent. better than a reciprocating engine working non-condensing, and the turbine is 100 per cent. better condensing than the turbine working non-condensing.

As time has gone on the turbine has become more and more efficient, and with the improvement in details, such as relative velocities, bucket shapes, the direction of the steam against the blades, etc., a very high efficiency has been reached, and we now have a turbine taking out 75 per cent. of the power—in fact, 76 and 77 per cent.—whereas, with a reciprocating engine through the best part of its range is not getting more than 76 and 77, and the reciprocating engine is working on a very much narrower range. The turbine's efficient range is from 250 pounds per square inch right down to any vacuum that can be produced, to 29 inches, and the means of producing vacuum have been improved in connection with turbine work.

The net result of all this is that the best reciprocating engines making electricity are producing, at their best point of power, about 18 pounds of steam per kilowatt, whereas with turbines

FIG. 4.

Stator frame and windings of generator, U. S. collier *Jupiter*.

we are down as low as 11 or 11.5. I think possibly that that statement is somewhat unfair, because superheated steam enters into that, and I will say that perhaps about 18; 13 would be a

FIG. 5.

Revolving field of generator, U. S. collier *Jupiter*.

fair ratio of comparison of the best turbines of to-day with the reciprocating engine existing before turbines were begun. On board ship the reciprocating engine is subject to just as great limitations as it is on shore, and in some cases it is subject to

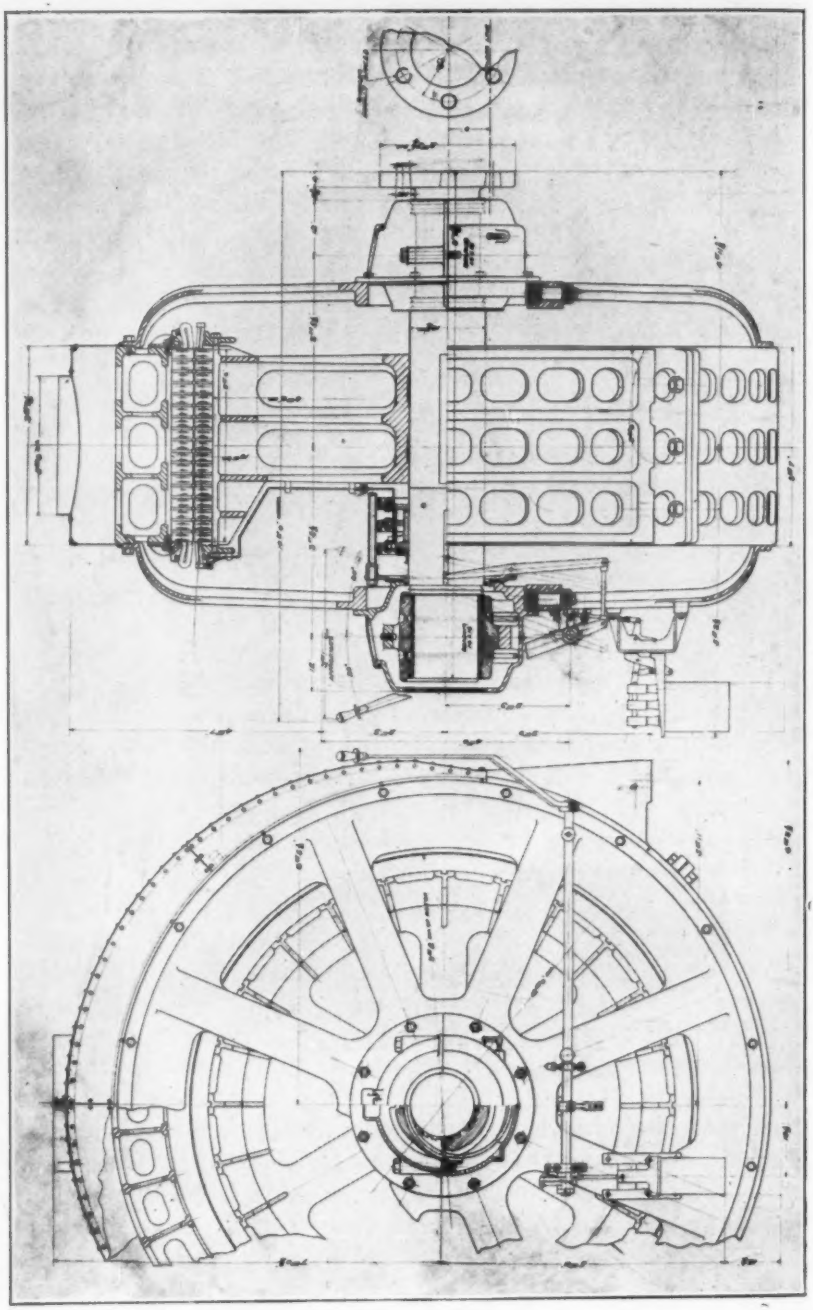


FIG. 6.

Cross-section of motor for U. S. collier *Jupiter*.

very much greater limitations. The difficulty about making reciprocating engines for economy is that the low-pressure cylinders become very large and heavy, and the valves and steam connections have to be made very large in order to get good economy. On board ship this is a very severe limitation in output. For instance, in a battleship, which has to make occasional high

FIG 7

Stator of motor for U. S. collier *Jupiter*.

speed, the engines, if of reasonable weight, must be badly congested when she runs at this maximum speed. In the first turbines made some of the same limitations existed to a certain extent; but the improved methods of building turbines have gradually eliminated these difficulties and made the turbine work effectively through a wider range, and made it smaller for its output on account of increased speed. This development had gone on for some time before it reached a point where electrical propulsion could be considered justifiable. In the *Mauretania*,

which is the best example of a turbine-driven ship, the turbine propeller speed is about 180 revolutions per minute, and each of the turbines has a capacity of about 17,500 horsepower. For shore purposes we make a turbine of 17,500 horsepower which runs at 1500 revolutions per minute. We could make it as high as 1800 revolutions per minute, so that the speed of our turbine for shore purposes is 10 times as high as those designed for shipping. This great difference of speed enables us to make the turbine extremely light. The desirable speeds of a ship's turbine and an electrical turbine may have a ratio of 10 to 1, and the size of the turbines is nearly in the same ratio. On the other hand, the propellers of the turbine ships are run at the limit of the speed in order to help the turbine, and these propellers are put far above the speeds which would be selected if the turbine itself was not considered. Advocates of ship turbines have done a great deal of work on high-speed propellers, and their arguments have all tended to crowd up the speed limits. The best authorities show wide variations of efficiency through such ranges of speed as are covered by these differences. The propulsive efficiency of ships is very low. It ranges from 45 to 60 per cent., possibly, and it works through ranges which are very large as compared with the variations of efficiency which we ordinarily consider in prime movers. Electricity affords a means by which we can adopt any propeller speed we please, and we can also adopt any turbine speed, and the desirable turbine speed and the desirable propeller speed being as they are, in many ships we find the ratio we would select is 18 or 20 to 1. That is, we run the turbine 18 or 20 times as fast as we run the propeller, whereas in the turbine ships these two are forced together.

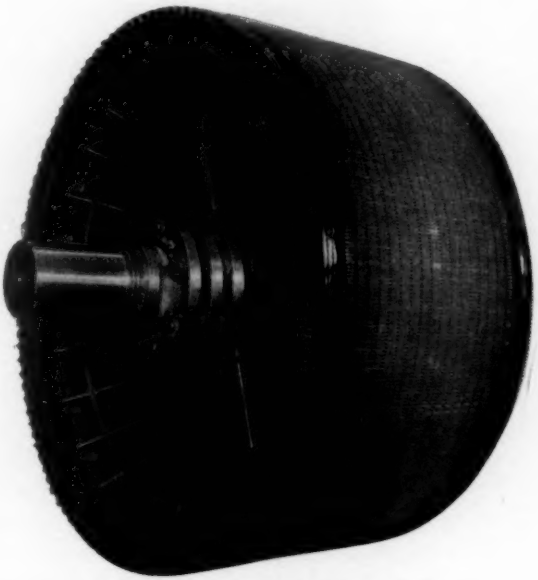
Now when this possibility of driving a ship by electricity began to loom up as an attractive proposition the question of gearing was discussed and advocated; that is, gearing helical spur type. The difficulty in the application of gearing to a ship varies with the rate of reduction necessary. It is easier in gearing anything to effect a small ratio than a high ratio, and the effective gearings that have been made up involve a rather small ratio of gearing.

The Parsons turbine is susceptible of a very good design for

moderate speeds. It is not very good for the extreme limits of capacity in high speeds, but for certain intermediate speeds it gives very good efficiency without very much complication, and it is therefore made quite attractive if we can have a gear with even a moderate reduction between the propeller and the turbine.

Sir Charles Parsons, who is a great engineer and a great man, has always done good work in everything he has ever

FIG. 8.



Rotor of motor for U. S. collier *Jupiter*.

touched. He has worked on this gearing a good deal and has got some very successful results, and the prospect of using gearing and the discussion of the possible use of gearing have tended to retard the development of electricity as a means of speed reduction.

Mr. George Westinghouse also has done some very excellent and interesting work on the development of gears for driving ships, and the gearing on the *Neptune* is a very good example. The turbines in her are not efficient, and as an engineering prop-

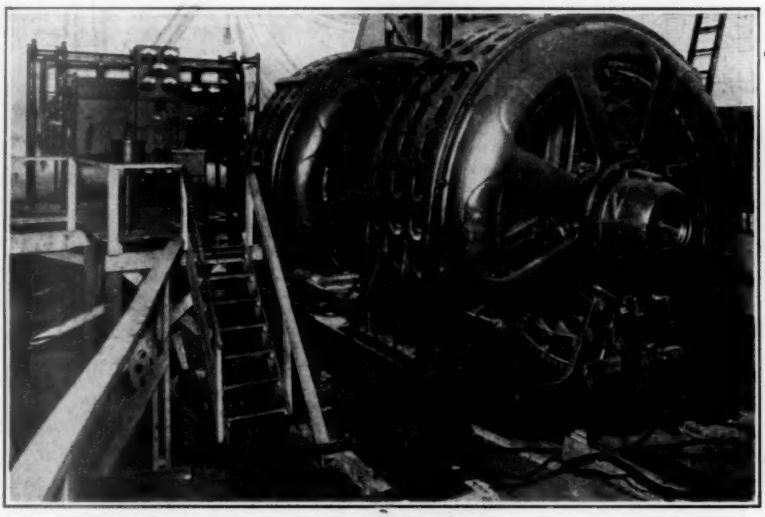
osition she was badly handled, so that the ship never had as good results as she ought to; but the gearing has been successful, so that we must regard gearing as a factor, and we must not say that electricity is justified because the gearing is not practicable. All indications are that the gearing is workable and is good. Large vessels will be harder to drive effectively by gearing than small vessels. The scope of the application of gears is unknown. They have only been applied to a limited extent, and we can see all kinds of difficulties as we go forward, but it is safe to say the gear will have an application; at least in smaller vessels it will be cheaper than electricity, and should have an extensive use.

However, the recent developments of the turbine have improved the prospects of electric propulsion so much that it would appear that no possible development of gearing could bring it to an equality with electricity as a means of speed reduction for large ships. In certain classes of vessels, as I say, we now can make turbines as high as, say, 25,000 horsepower with a speed of 1800 revolutions per minute, and these turbines have an efficiency of 75 per cent., and they are so small and so compact that it is enormously advantageous in a ship to use them. The electrical apparatus involves a certain weight, and weight involves a certain loss, but in large vessels that weight and loss is small and relatively unimportant, and the simplicity of electrical reduction is entirely in its favor, although people unfamiliar with the use of electricty have been disposed to think badly of it on the score of complication. The electrical machinery for this purpose is so well known that any engineer can analyze the designs proposed, and he cannot condemn them on the ground of possible trouble, for the reason that all sorts of machinery are being run by electricity under greater difficulties. In the case of ship propulsion the matter is particularly simple, because we only make as much electricity as we require, and we simply supply what we need, and there is no trouble from short-circuiting, and the largest power that comes from the generator is incapable of burning out any conductor in it. There is no waving conductor in the system, and the voltage is low. It is convenient for installation, and the voltage and the character of the apparatus is such that in twenty years of experience

on shore with that particular kind of apparatus and voltage there is hardly a single case of insulation failure.

The method which we propose for propelling ships by electricity is the combination of a simple 3-phase alternator with induction motors. Such design is used in the *Jupiter*, now being built on the Pacific coast. Her motors have resistances in their secondaries, which resistance is needed in getting a large torque to reverse. We have recently devised ingenious

FIG. 9.



U. S. collier *Jupiter*—Motors set up for test. One being used as a generator to load the other.

means in motor design by which we can dispense with that resistance and can reverse the propellers without this complication. The rotor becomes a squirrel-cage design, and the only high-voltage, current-carrying conductors in the system are on the stationary parts. This is a great advantage, and we have also developed it in such manner that we can stop, start, and reverse by simply opening and closing switches without disturbing the excitation. There has been, in connection with this development, so much designing that it is a little difficult to say where to stop in explanation. You want to remember that the object is speed reduction and the method is fundamentally

FIG. 10.

Water-cooled rheostat, U. S. collier *Jupiter*.

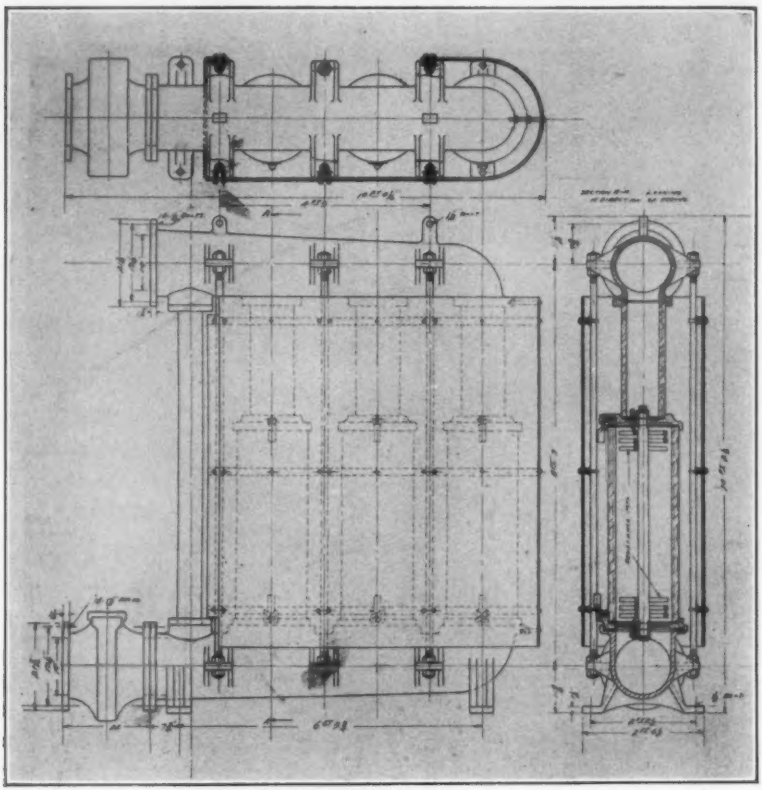
simple as compared with the simplest apparatus that is used on shore for general purposes.

Among the pictures which I will show you are curves relating to the collier *Jupiter,* now being built at the Mare Island Navy Yard, a ship of about 20,000 tons capacity displacement. She is a sister ship to the *Neptune,* which has been fitted with the Westinghouse gears, and of the *Cyclops.* The *Jupiter* will be equipped with turbines and will be run, I think, about next May. We first built the *Jupiter's* apparatus under certain specifications which we made for the Government. We made certain predictions as to results which would be accomplished, and we made certain guarantees. The test of the apparatus last June showed the performance was slightly better than our prediction—190 pounds steam pressure and 28.5 inches vacuum and saturated steam would give 12 pounds per horsepower on the propeller shafts; but just previous to these tests we began to get new light on the matter of turbine design; we found means to produce better efficiency. I was very anxious at that time to get the earliest possible data on these improved methods, because it was useful to us in much of our work, and, while the *Jupiter* had met our predictions, I also wanted to get the best standard of efficiency in this installation. The new type of design being simpler than that first built, we decided to change the generating unit, and we got permission from the Government to make the change.

We recently tested this new generating unit, and the results produced by it bring the water rate .9 pound lower. It will be about 11.1 pounds per shaft horsepower under the conditions I have stated. This generating unit has given results far better than anything that has been produced from any turbine unit in the world. About the best recorded performance of a turbine which had previously been generally credited was that of a Parsons turbine in Dunston Station, in Newcastle, England, accounts of which were published about a year ago. This machine, with 220° superheat and 29 inches vacuum, produced an efficiency of 68.6 per cent. In our test we could not produce such a high degree of superheat; we only tested at a little above 100, but we tested it at various degrees of vacuum. The projection of our curves to the same degrees of superheat and

vacuum as at Dunston Station shows an efficiency of 73 per cent., as against 68.6 per cent., which is a pretty big gain to make in a prime mover; so that, while the *Jupiter* was only a moderately good case for electric ship propulsion by electricity, we will

FIG. 11.



Water-cooled rheostat, U. S. collier *Jupiter*.

make a pretty good demonstration. I think that since this contract has been made the interest in this subject has steadily increased and grown.

We have been figuring recently—through the British Thomson-Houston Company—on a very large ship in England, and the results we show, based on actual tests of apparatus at Schenectady as possible on that ship, are so good that the owners

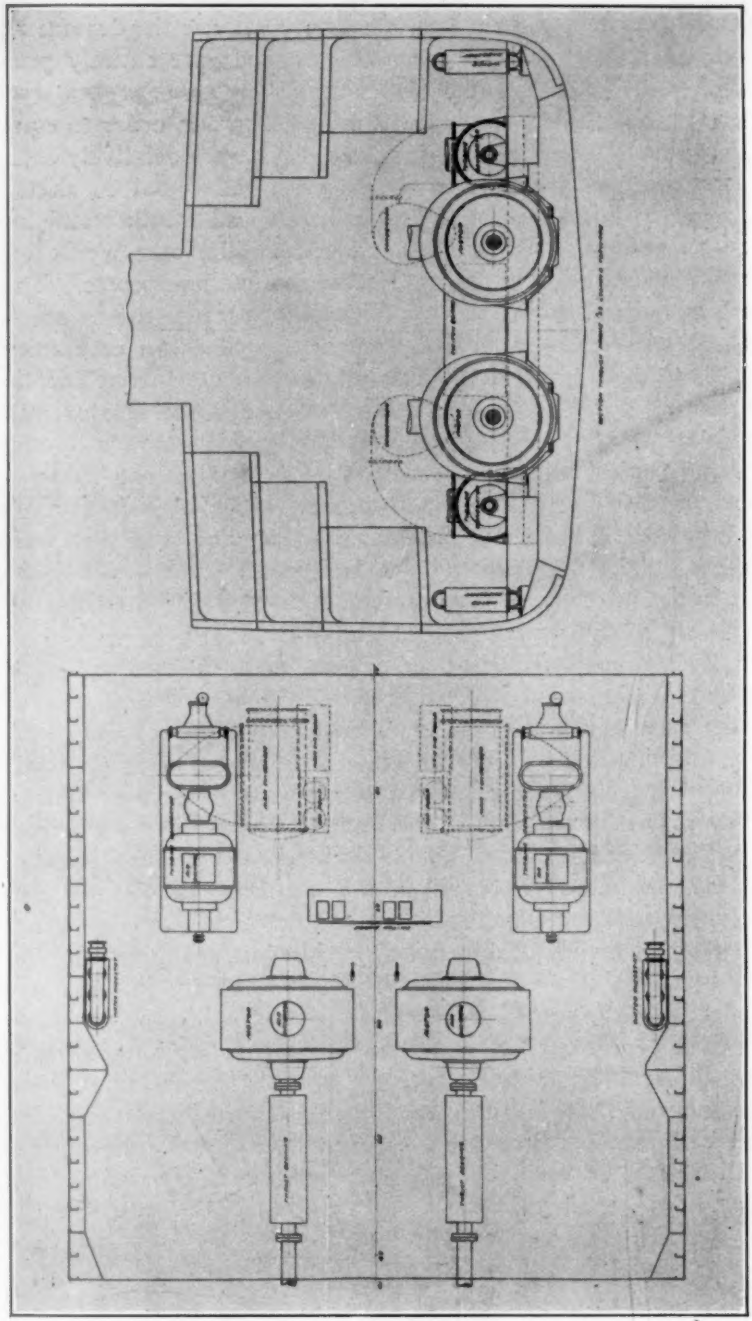


FIG. 12.

Arrangement of apparatus for electric propulsion of a large liner.

simply cannot turn their back on it, especially if the demonstrations on the *Jupiter* show that the methods are entirely practicable, as we are sure they will.

I learned to-day that we will probably get an order to equip a large and fast yacht. This vessel will have a relatively small power, and in this respect is not very well suited to electric propulsion, but on account of the high-speed turbines and improved designs which we have developed the case works out very well and is in every way attractive to these people. This case is something like that of a warship, because they want to run at an economical cruising speed as well as an economical high speed. In my designs as applied to merchant ships the turbine is slowed down for low speed, but in the case of warships we arrange to change the ratio of speed reduction by connecting for different numbers of poles so that we can run with one range for high speeds and another range of reduction for low speeds, and we will probably do the same with this yacht with a certain degree of advantage, though not as much as we get in the warship; if this is done, it will demonstrate the practicability of the method for warships.

The *Jupiter* is designed for a speed of 14 knots; the *Cyclops* made 14.6 knots in her trials, and this vessel has equivalent boiler capacity. She is designed with a view to receiving reciprocating engines, and the turbines are simply put in the space which the reciprocating engines would occupy, and our contract reads in such a way that if we do not do all that we predict our machinery will be lifted out on the dock and the reciprocating engines put in, and there will simply be a little time lost. I think it proper that the Government should have made due provision for the possibility of substituting reciprocating engines, because this method is new. I am very sure that when this ship has been run the general fear of electrical propulsion will change, because she will be successful. I say this because I am an electrician and am familiar with electricity. It is the easiest thing I do. Other people have a different view of such things and have not acquired the electrical habit. When they do acquire it, they will want to do everything by electricity, and they will in most cases be right.

NOTES ON ELECTRIC FIELD DISTRIBUTION.*

BY

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Professor of Physics, Lehigh University.
Member of the Institute.

SEVERAL of my former students have asked me where they might look up the electrostatic theory that is necessary to fully understand the important paper which was read before the American Institute of Electrical Engineers, on March 14, by Mr. C. Fortescue, on "Insulation Problems," and, in view of these requests, it seems worth while to publish the following discussion of Mr. Fortescue's paper which was given before the instructing staff and students of the Departments of Physics and of Electrical Engineering at Lehigh University. The discussion is made as brief as possible, and it is assumed that the diagrams will make the meaning clear.

The following propositions are extensively used in theoretical discussions of electrostatics:

(*a*) *Any equipotential surface may be wholly or in part replaced by a thin metal sheet without disturbing an electric field distribution.* Thus Fig. 1 shows the lines of force between two metal cylinders *A* and *B*. The dotted line represents an equipotential surface, and this equipotential surface may be replaced wholly or in part by a thin metal sheet without disturbing the field between *A* and *B*.

(*b*) *A closed metal shell screens its interior from all outside electrostatic effects.* This action of a metal shell may be understood in terms of a mechanical analogue as follows: Fig. 2 represents a mass of steel *B* completely separated from a surrounding mass of steel *A* by an empty space. The steel *B* remains unstressed however the steel *A* may be stressed, because stress cannot be transmitted across an empty space. Fig. 3 represents a mass of dielectric *B* completely separated from the surrounding dielectric *A* by a metal shell. The dielectric *B* remains unstressed however the dielectric *A* may be stressed,

* Communicated by the Author.

because electrical stress cannot be transmitted through metal. A very rapidly changing electrical stress can, however, be transmitted through metal to a slight extent.

THE METHOD OF ELECTRICAL IMAGES.

It is easy to formulate mathematically the distribution of electric field due to an electric charge which is thought of as being concentrated at a *point* or along a *line*, and the formulation of ideal problems of this kind furnishes the basis for the solution of some of the important practical problems in electric field distribution. Thus the fine lines in Fig. 4 represent the

FIG. 1.

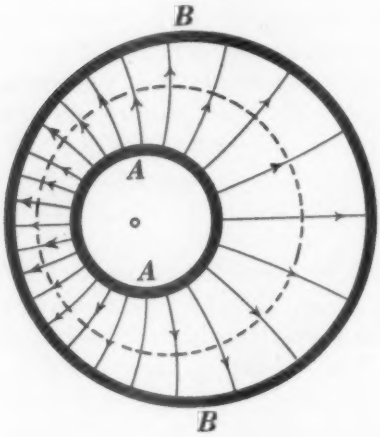
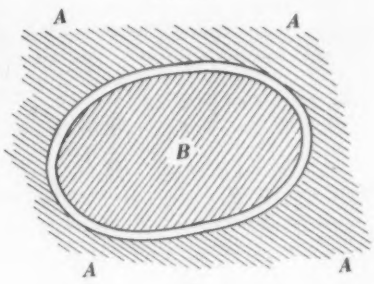


FIG. 2.



electric lines of force around a long, straight linear charge (a charge on a fine wire, the wire being very small and perpendicular to the plane of the paper). The potential at any point p in Fig. 4 is equal to

$$2Q \log_e r - 2Q \log_e r_0,$$

where r is the distance of the point p from the axis of the wire, Q is the charge per unit length of the wire, and r_0 is the distance from the axis of the wire to the chosen region of zero potential. This expression for the potential due to a linear charge is fully discussed in most text-books on electrostatics.

The equipotential surfaces in Fig. 4 are cylinders, as represented by the dotted circles. If the inner circle, in Fig. 4, be

replaced by a solid metal rod and the outer circle by a hollow metal cylinder, as shown in Fig. 5, the electric field in the intervening space will remain unaltered. Therefore the distribution

FIG. 3.

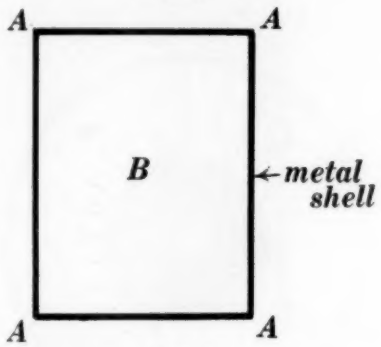
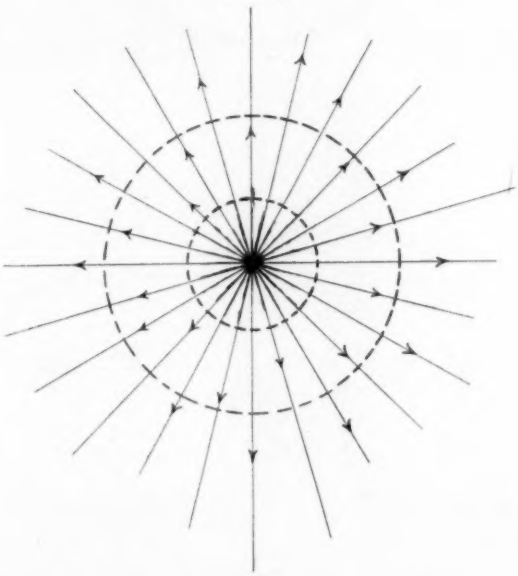


FIG. 4.



of electric field around an ideal linear charge as shown in Fig. 4 leads to the solution of the problem of the distribution of electric field in the insulation of a cable as shown in Fig. 5.

Fig. 6 shows the electric field distribution between two long, straight, parallel equal but oppositely charged lines, the lines be-

ing at right angles to the plane of the paper. The expression for the potential at any point p in Fig. 6 is

$$2Q \log_e \left(\frac{r_1}{r_2}\right),$$

FIG. 5.

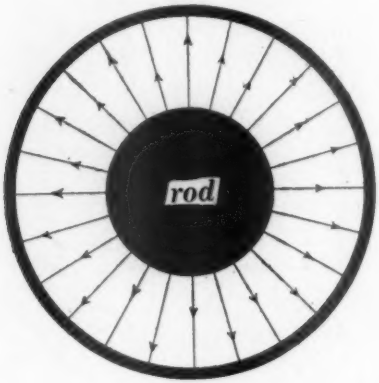
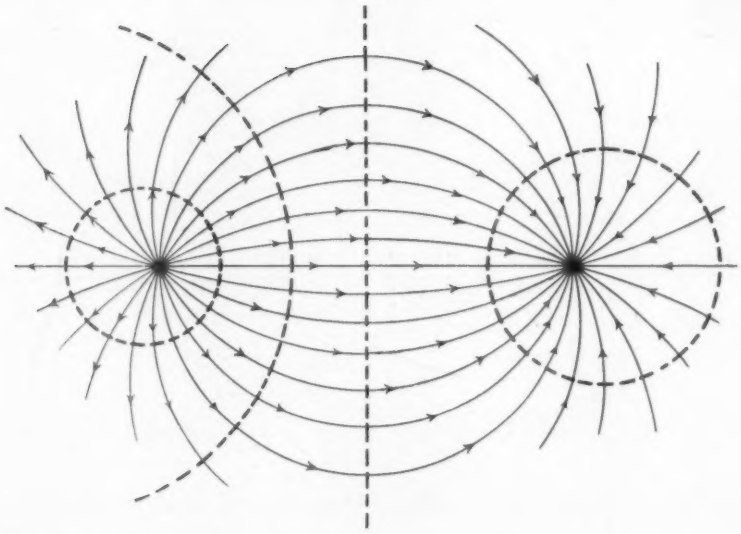


FIG. 6.



where Q is the charge on the lines per unit length, positive on one line, negative on the other, r_1 is the distance of p from one line, and r_2 is the distance of p from the other line. This ex-

pression for the potential due to two linear charges is easily found from the expression for the potential due to one linear charge.

FIG. 7

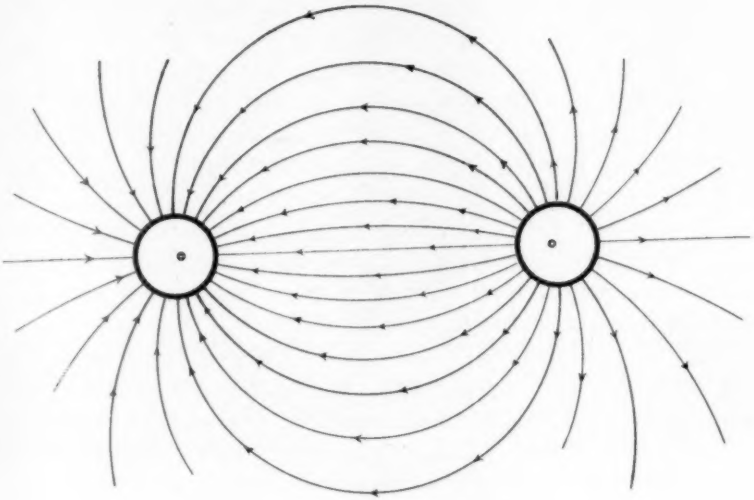
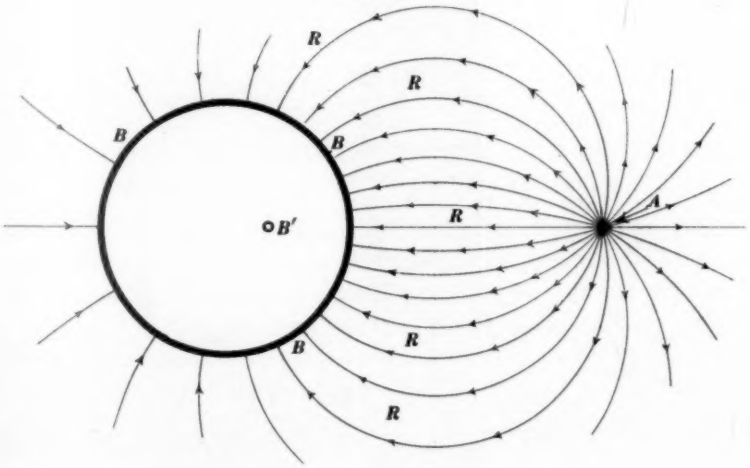


FIG. 8.



The equipotential surfaces in Fig. 6 are circular cylinders as represented by the dotted circles, and the equipotential surface midway between the linear charges is a plane. Fig. 7 shows

two of the equipotential surfaces of Fig. 6 replaced by metal cylinders. The distribution of electric field between parallel metal cylinders as shown in Fig. 1 or Fig. 7 is the same as the distribution of electric field in Fig. 6. Therefore the mathematical formulation of Fig. 6 leads to the complete solution of the problem of electric field distribution around or between parallel cylinders. Approximate formulas are nearly always used in connection with the problem of parallel cylinders, however, because the rigorous formulas are rather complicated, as will be understood by reading pages 273 to 277 of Franklin's "Electric Waves."

A great variety of particular problems relating to electric field distributions can be set up and solved by the method of images as exemplified by Figs. 1, 4, 5, 6, and 7; and the origin of the term electric image may be understood with the help of Fig. 8. The electric field distribution between a linear charge A and an oppositely charged metal cylinder BB is identical to the electric field distribution which would be produced in the region RR by a line charge at A and an opposite line charge at B'. The easiest basis for the mathematical formulation of the field RR in Fig. 8 is, therefore, to think of the field as being due to the two linear charges A and B'. The fictitious linear charge B' is called the electric image of A with respect to the cylinder BB.

THE PRODUCTION OF ANY DESIRED FIELD DISTRIBUTION IN A REGION BY THE CREATION OF PROPER POTENTIAL VALUES EVERYWHERE OVER THE BOUNDARY OF THE REGION.

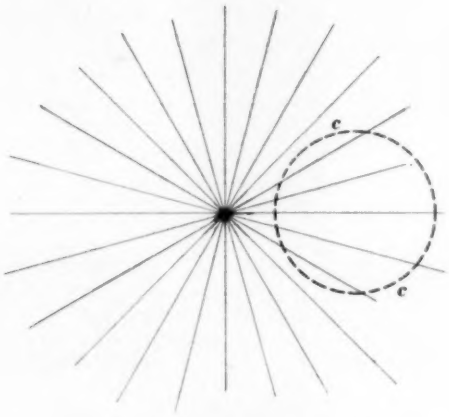
The distribution of electric field in a region depends upon two things; namely, (*a*) the potential values over the boundary of the region and (*b*) the distribution of electric charge in the region. *When there is no charge in the region the boundary values of potential determine the field distribution.* Therefore, if it is desired to produce any assigned field distribution in a given region (a field distribution which is not associated with electric charge in the region, or, as it is usually expressed, an electric field which has no divergence [1] in the region), it is suffi-

[1] A very simple discussion of the important ideas of *divergence* and *curl* is given in Chapter IX of Franklin, MacNutt and Charles's "Calculus," published by the authors, South Bethlehem, Pa., 1913.

cient to create the proper potential values over the boundary of the region.

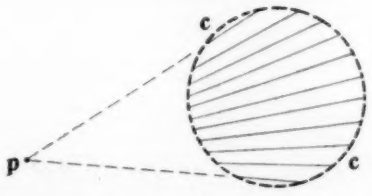
Example 1.—Fig. 9 represents the lines of force surrounding a linear charge. The dotted circle in Fig. 9 represents a cylinder parallel to the linear charge. Imagine this cylinder to

FIG. 9.



be made of narrow insulated strips of metal as represented by the separate dots of the circumference, and imagine each strip to be brought by proper means to a potential equal to the potential at the strip due to the linear charge in Fig. 9. We would thus have the potential fixed at every point on the dotted cylinder

FIG. 10.

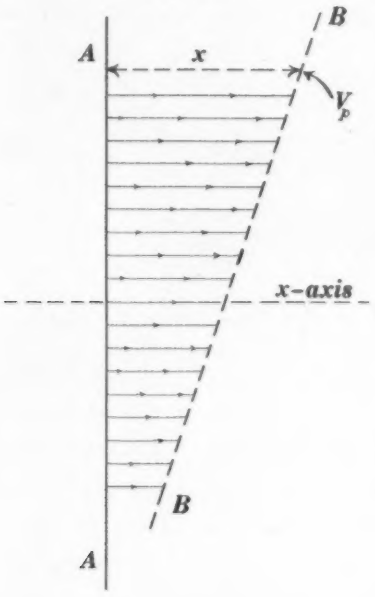


in Fig. 9, and the electric field distribution inside of the cylinder would be as shown in Fig. 10, irrespective of the electric field outside of the cylinder. Fig. 10, therefore, is an example of the production of a desired electric field distribution in a given region by bringing the various parts of the boundary of the region to the proper potential values.

Example 2.—A metal sheet AA (Fig. 11) is at zero potential, and a series of insulated metal strips BB very close together and perpendicular to the plane of the paper are brought by proper means to potential values such that the potential V_p of any strip is proportional to its distance x from AA. Under these conditions the region between AA and BB will be a uniform electric field, as indicated by the lines of force in Fig. 11.

The method illustrated in Figs. 10 and 11 for producing any assigned electric field distribution in a given region is used by

FIG. 11.



Mr. Fortescue in the designing of insulating structures. Let it be required, for example, to produce a uniform electric field parallel to the y-axis in the region of the coarse lines of force in Fig. 12, and a cylindrically radiating electric field in the region of the fine lines of force in Fig. 12. By cylindrically radiating field is here meant a field which radiates from the y-axis in an uncharged region.

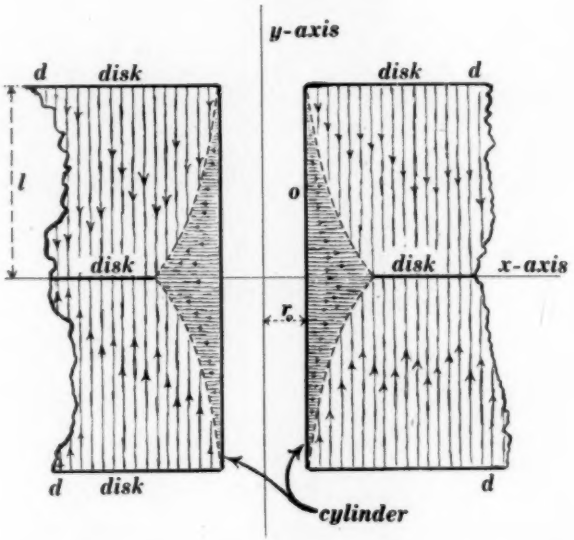
Let us assume that the cylinder of radius r_0 and the end disks dd are at zero potential, and let us consider the potential

at any point p of which the co-ordinates are x and y. The potential at p due to the radial field is

$$k \log_e x - k \log_e r_o,$$

where k is a constant, on the assumption that the radial field reaches to p; and the potential at p due to the uniform field is $fl—fy$, where f is the intensity of the uniform field. The locus of the points where the two fields give the same potential is represented by the dotted curve in Fig. 12, and its equation is gotten by equating the above expressions for potential.

FIG. 12.



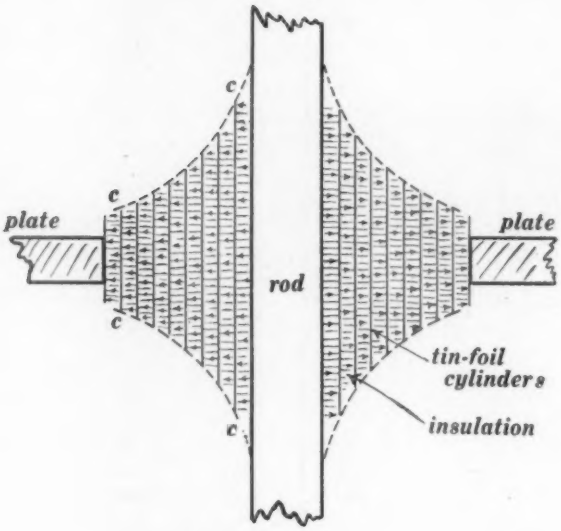
Now, in order that the two fields as indicated in Fig. 12 may be actually obtained, it is sufficient to have the tube and the end disks at potential zero, to have the middle disk at potential fl, and to provide a number of rings of tin foil (as represented in section by the dots of the dotted curve in Fig. 12) along the common boundary of the two fields, these rings being brought by proper means to potentials which conform to both fields.

The radial field of which the potential is

$$2Q \log_e r + \text{a constant}$$

is the only type of field which can radiate from an axis in a region where there is no charge. If it is desired to produce a radial electric field which remains constant in value with increasing distance from the axis, it is necessary to provide a series of coaxial cylindrical leaves of metal as shown in Figs. 13 and 14. Fig. 13 shows the well-known condenser type of insulating bushing. The theoretically correct shape of the curve *cc* in Fig. 13 is an equilateral hyperbola, because in this type of bushing the successive tin-foil cylinders must have the same area. No attempt is made in Fig. 13 to represent the distribu-

FIG. 13.

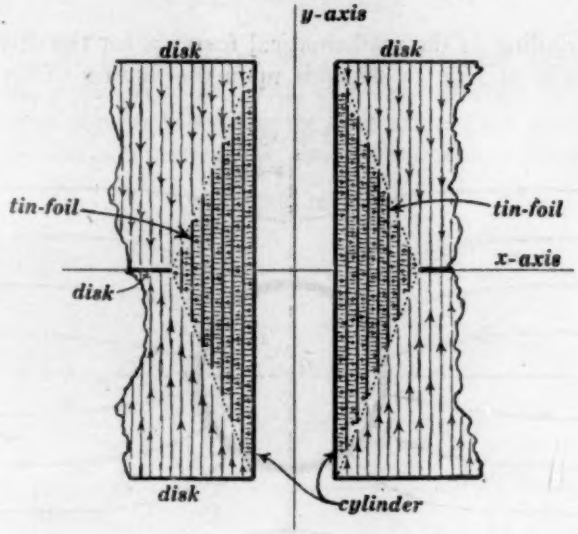


tion of the electric field in the region surrounding the bushing. As a matter of fact, this electric field is very greatly concentrated in the region immediately surrounding the rod at the ends of the bushing.

Fig. 14 shows the method suggested by Mr. Fortescue for eliminating the concentration of electrical stresses at the ends of the bushing in Fig. 13. There is a constant potential difference between successive tin-foil cylinders in Fig. 14, and therefore, if the potentials of the successive tin-foil cylinders are to be conformable to the uniform electric field which is represented by the coarse lines of force in Fig. 14, it is necessary to ter-

minate the cylinders along the dotted straight lines as shown in Fig. 14. With this arrangement, however, the tin-foil cylinders do not all have the same area; and, therefore, to provide for equal potential steps between successive tin-foil cylinders, it is necessary to connect the successive cylinders to the proper points in the winding of the transformer.

FIG 14.



UNIFORM ELECTRIC FIELD MODIFIED BY A CYLINDRICAL CONDUCTOR.

Fig. 15 shows the lines of force in the neighborhood of a metal cylinder of radius r in a region which would be a uniform field at right angles to the axis of the cylinder if it were not for the distorting influence exerted on the field by the metal cylinder. The mathematical formulation of the field distribution in Fig. 15 is accomplished by the method of images as follows:

Consider two opposite linear charges parallel to each other and at a distance dx apart, and let $+Q$ and $-Q$ be the charges per unit length, where $Q.dx$ is a finite quantity. Such a pair of linear charges is called a *linear doublet,* and the product $Q.dx$ $(=M)$ is called the *moment* of the doublet.

The potential at a point due to a linear doublet is found

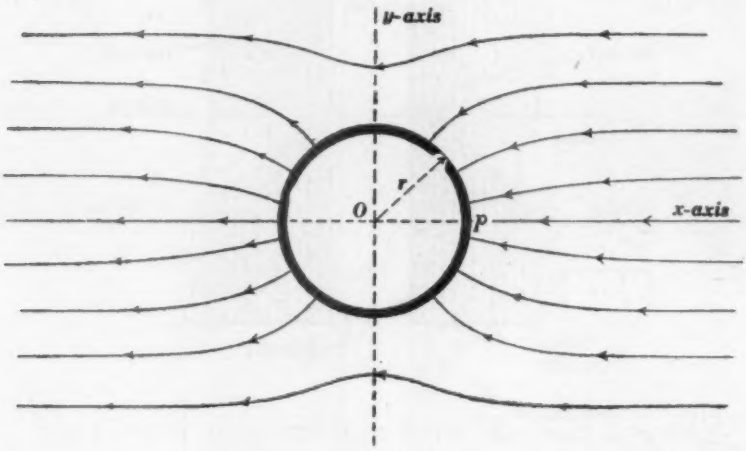
with the help of Fig. 16 as follows: The potential at the point p in Fig. 16 due to the linear charge $+Q$ is $2Q \log_e (r + \Delta r)$,[2] and the potential at p due to the linear charge $-Q$ is $-2Q \log_e r_0$. Therefore the net potential at p due to the doublet is

$$2Q [\log_e (r + \Delta r) - \log_e r] = 2Q \frac{d (\log_e r)}{dr} . dr$$

$$= 2Q \frac{1}{r} . dr = 2Q \frac{1}{r} \cos \theta . dx = 2M \frac{\cos \theta}{r} .$$

The finding of the mathematical formula for the distribution of potential in Fig. 15 depends upon the finding of an expres-

FIG. 15.



sion for potential which will give a constant potential over the surface of the cylinder, but which at great distances from the cylinder will reduce to the potential which is associated with the uniform field. This condition is met by superposing the potential due to a linear doublet upon the potential which is associated with the uniform field.

The above expression for the potential of a linear doublet is based upon the choice of the y-axis in Fig. 15 as the region of zero potential, and the expression for the potential which is associated with the uniform field in Fig. 15 is $-fx$, where f is

[2] The undetermined constant $2Q \log_e r_0$ is here ignored because it drops out anyway.

the intensity of the field. This field is directed toward the left in Fig. 15. Therefore the potential due to the uniform field and to the linear doublet together is:

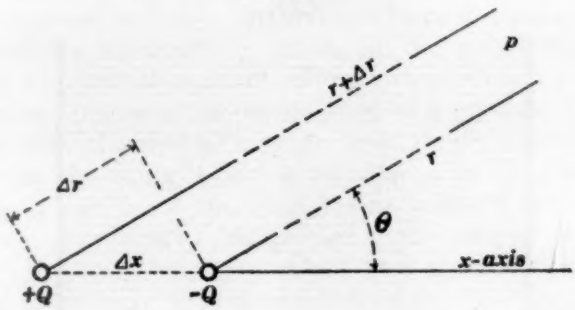
$$V = 2M\frac{\cos\theta}{r} - fx \qquad (1)$$

But $x = r\cos\theta$, so that this equation becomes:

$$V = \left(\frac{2M}{r} - fr\right)\cos\theta \qquad (2)$$

If r is the radius of the metal cylinder, this equation expresses the potential of the metal cylinder. But the metal cylinder has zero potential, because we have chosen the y-axis as the region of zero potential in the above discussion. Therefore, V

FIG. 16.



as given by equation 2 must be zero when r is the radius of the metal cylinder. Therefore the expression in the parenthesis must be equal to zero, or we must have:

$$M = \frac{1}{2}fr^2, \qquad (3)$$

which gives the moment of the linear electric doublet to be placed along the axis of the metal cylinder in Fig. 15 to give (when the cylinder is taken away) the field distribution which exists in Fig. 15 in the region outside of the cylinder. The linear doublet is the image in the metal cylinder of the external influence which is the cause of the uniform field in Fig. 15.

It is evident, from Fig. 15, that the presence of the metal cylinder produces a concentration of the electrical stress, the maximum of stress being at the point p. The field intensity at p may be considered in two parts, namely (a) the part $-f$

which is associated with the uniform field, and (b) the part which is associated with the linear doublet. This second part is found by taking the value of $\frac{dV}{dx}$ at p, where V is the potential due to the doublet. But at p (and all along the x-axis) the potential due to the doublet is

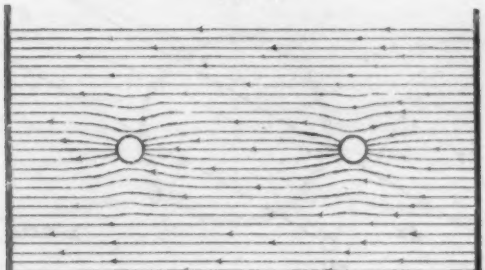
$$V = \frac{2M}{x}$$

so that

$$\frac{dV}{dx} = -\frac{2M}{x^2} = -\frac{2M}{r^2}$$

because $x = r$ at p. Substituting the value of M from equation 3, we get $-f$ for the intensity at p of the field due to the doublet. Therefore the total intensity of the field at p is equal to $2f$, and

FIG. 17.



it is, of course, negative, being directed toward the left in Fig. 15.

In the above discussion the radius of the metal cylinder may be anything whatever. Therefore if a wire of any radius is stretched across a region which, but for the presence of the wire, would be a uniform field of intensity f at right angles to the axis of the wire, then the presence of the wire causes a local concentration of electric stress (at the point p in Fig. 15), and the maximum electrical stress thus produced is $2f$.

In the case of two ordinary line wires the electrical stress is greatly concentrated near the wires, especially if the wires are small. Indeed, the maximum stress in this case is:

$$f_{max} = \frac{E}{2R \log_e\left(\frac{D}{R}\right)}$$

where R is the radius of the wires, D is their distance apart centre to centre, and E is the voltage between the wires. Now this maximum stress may be very large indeed for given values of E and D, but the maximum stress is reduced to $2 \times \frac{E}{D}$ by superposing a uniform field of intensity $\frac{E}{D}$ as indicated in Fig. 17. This exemplifies Fortescue's method of doing away with excessive concentrations of stress by the superposition of a uniform field.

THE WORD POTENTIAL AN OBSESSION.

One reason why Mr. Fortescue's paper is difficult to read and understand is that he follows the common practice in making almost exclusive use of the idea of *potential*, whereas the ideas of *field strength* and *lines of force* are more distinctly physical, and therefore more clearly intelligible in verbal discussions. The idea of potential is useful only when one is ready to proceed to the actual mathematical formulation of a problem.

The idea of potential may be most simply exemplified by considering the uniform field as represented by the coarse lines of force in Fig. 12. If this field has an intensity of f volts per centimetre everywhere, and if the upper disk dd is at zero "volts," it follows that the "volts" at a point p which is at a distance of $(l—y)$ centimetres from dd is $f(l—y)$. Now, no doubt, the great majority of electrical men are shocked when one speaks of the "volts" *at a point;* and, of course, physically speaking, there is no such thing; and yet electrical men speak glibly of the "potential" at a point.

The electric potential at a point is the "height" at that point of an imagined "hill" whose "slope" is everywhere equal to the electric field intensity.

Some electric field distributions can be looked upon as *slopes* or *gradients,* and such electric field distributions have potential.

Some electric field distributions cannot be looked upon as *slopes* or *gradients,* and such electric field distributions do not have potential.

It is of the utmost importance, especially in discussions leading up to mathematical formulations, to use ideas which have direct connection with physical conditions and things. Thus every one realizes the importance of such ideas as the tempera-

ture at a point, the temperature gradient at a point, the pressure at a point in a fluid, the energy density at a point in an electric field, the velocity of a fluid at a point, the intensity of an electric field at a point, and so on. And we believe with Heaviside that even the correct use of the word potential tends to turn one's attention away from physical things. Every one, and especially those whose ideas are mere thought-habits, will admit the fictitious character of the *velocity potential of a fluid*, namely, the "height" at a point of an imagined "hill" whose "slope" is everywhere equal to the fluid velocity; but with electrical potential it is different! The word potential (we say the word because very few indeed use the idea) has become an obsession. The magic word energy appears in one of the legitimate definitions of potential, and that settles the matter! Energy, "the only real thing in the universe," as one teacher exclaims! Let us cease talking energy and talk sense, and above all let us keep clear of such blunders as to say "Electric potential may be defined as the condition at a point in space which determines the direction in which an electrified body placed at that point would tend to move." One might as well say that the height of a hill at a place is the condition which determines the direction in which water will flow at that place. The fact is that 99 per cent. of those who use the word potential do not think of potential at all; they think of a vague-composite-of-field-intensity-and-energy-and-other-things - too - indefinite - to-specify. The generalized ideas of *height* and *slope* have never entered their heads. They do not know that potential is related to electric field as slope is related to height of a hill; and they do not know that *the idea of potential is helpful only when one is concerned very particularly with the mode of distribution of an electric field in space.*

Decomposition Constant of Polonium. E. v. SCHWEIDLER. (*Verh. Deutsch. Phys. Ges.*, xiv, 536.)—The half-time period of polonium was determined quite accurately by means of experiments extending over several years, thus reducing the sources of error. The value obtained was 136.5 ± 0.3 days, which is in close agreement with Regener's value of 136.0 ± 0.5 days. The activity of the preparation was determined by a direct galvanometric and by an electrometric method.

THE PHYSICAL LABORATORY OF THE NATIONAL ELECTRIC LAMP ASSOCIATION.

A Résumé of the Activities of the Laboratory in the Development of the Modern Science of Illumination *

BY

EDWARD P. HYDE, Ph.D.,

Director of the Laboratory, Member of the Institute.

THE rapid, unparalleled development of the science and art of illuminating engineering is in itself an unanswerable argument for the necessity and value of this, the most modern of the engineering professions. Seven years ago illuminating engineering was but a name known to a few enthusiasts who foresaw the wonderful possibilities in the development of the science of illumination and in the application of that science to the design of illumination installations. The Illuminating Engineering Society of the United States was organized in the early part of the year 1906, and the total number of charter members amounted to only 89.

Now, seven years later, the society has an enrolment of 1400 members, scattered throughout the United States, with a few in Europe, and among its members are to be found physicists, physiologists, psychologists, ophthalmologists, architects, decorators, and representatives of other professions, in addition to those engineers who either directly or indirectly are interested in the application of lighting. On its committees are men of international reputation who are giving their efforts to the development of the science of lighting and to the spread of the gospel of good illumination. The initiative in the movement which resulted in the adoption of a common unit of candle-power for the photometry of gas and electric lamps in this country and in an international agreement on a common unit of candle-power for England, France, and the United States was taken by the Committee on Nomenclature and Standards of

* Presented at the meeting of the Section of Physics and Chemistry, held Thursday, January 30, 1913.

the Illuminating Engineering Society. The inauguration of the course of lectures on illuminating engineering which were delivered at the Johns Hopkins University in the fall of 1910, and which consisted of 35 lectures, delivered by 23 different lecturers, each of whom is an authority in the branch on which he lectured, is to be ascribed to the initiative of the Illuminating Engineering Society. The co-operation with the New York State Board of Factory Inspection in the formulation of bills for legislative enactment in the matter of factory lighting, the stimulation of co-operation with other technical societies through the establishment of reciprocal relations, and the suggestion of an international system of nomenclature and standards in illuminating engineering,—all these and other, activities of the Illuminating Engineering Society are unmistakable evidence of the earnestness and enthusiasm of members of the society, and indicate in a small way the magnitude of the almost unlimited field of activity which should develop in the performance of its legitimate functions.

Illuminating engineering as a distinct engineering profession had its origin in the United States, and has attained to the highest development in this country. The science and art of illumination are now, however, appreciated throughout the civilized world. Four years ago an illuminating engineering society was formed in England, and since its inception this society has done much toward the development of the principles of illuminating engineering and toward the propagation of those established principles. In the past year representatives of the Verein von Gas und Wasserfachmännern and of the Elektrotechnische Verein in Germany have united in requesting the Reichsanstalt to take the initiative in the organization of a German illuminating engineering society. These requests have resulted in the organization of such a society in Germany. There are other important indications of the growing appreciation of the necessity and value of illuminating engineering which might be cited, but they are unnecessary. The experimental stage has been passed, and we all recognize now the *raison d'être* of illuminating engineering and look to it for results comparable with the opportunities which stretch out before it.

Illuminating engineering is a modern science and art, and yet its principles rest on the correlation, after a new scheme, of the

scattered phenomena of the ancient sciences of physics, physiology, and psychology, and the dicta of the ancient art of architecture. In building up and developing the scientific principles of illuminating engineering, therefore, we are forced continually to draw upon the scientific development of the past as recorded in the scientific literature. Many investigators in many different laboratories have contributed to the establishment of the basic principles of illuminating engineering, and have made it possible that application in the art of illuminating engineering should begin contemporaneously with the organization of these scattered principles in the new science of illuminating engineering.

The success of this new science, and therefore of this new art, will depend upon the establishment of sound basic principles. Hence it is of paramount importance that we give our constant attention to the development of the principles of the science, lest its vitality be sapped by the injudicious application of unwarranted assumptions.

One of the many active forces at work at the present time in developing those correlated sciences which form the scientific basis of illuminating engineering is the Physical Laboratory of the National Electric Lamp Association. Four years ago, when the laboratory was in many respects more anticipated than real, a brief description of its purposes and objects was presented before the Illuminating Engineering Society. It may, therefore, be of some interest now, after almost four years of active work, to describe again the equipment of the Physical Laboratory of the National Electric Lamp Association and to present a *résumé* of the activities of the Laboratory in the development of the modern science of illumination. The purposes and objects of the laboratory are so intimately associated with the development of the basic scientific principles of illuminating engineering that it may well have been called the Illuminating Engineering Research Laboratory. In order, however, to emphasize its purpose of developing the pure science rather than the applied art of illuminating engineering, and to distinguish it from the many other research laboratories which have for their object the technical development and improvement of some commercial commodity, it has been called simply the Physical Laboratory. But, although for simplicity it has been given this name, its functions are not confined to physics. As we shall see later, some of the most

important problems investigated lie in the domain of physiology and physiological optics.

The Physical Laboratory had its inception in the spring of 1908, when an invitation from the Advisory Board of the National Electric Lamp Association to organize a laboratory for the study of the sciences on which lighting depends was accepted by the writer. In the fall of the same year the duties of the office were entered upon and plans were initiated for the organization of the work. The first year was occupied in supplying suitable quarters and facilities for the work and in selecting a suitable staff of collaborators and assistants. The building which was remodelled to become the first home of the laboratory is that in which Mr. Charles F. Brush developed many of his inventions. In some respects it is well adapted for physical research, but its close proximity to railroad tracks, with the resultant magnetic (and particularly the resultant mechanical) disturbances, renders it entirely unsuitable for radiation and other work requiring the use of sensitive galvanometers and similar instruments. We are now looking forward with keen pleasure to the occupancy, in the near future, of the new laboratory building which is being constructed in the suburbs of Cleveland.

The new building, which has been designed to meet the special requirements of the Physical Laboratory, is a two-story-and-basement structure, 128 feet long and, on the average, 38 feet wide.

As the building will not be entirely ready for occupancy for several months it probably would be premature to attempt to describe it in detail at this time. I might say that each room of the laboratory will be supplied with hot and cold water, gas, pressure, vacuum and a switchboard giving connections to storage batteries and direct- and alternating-current machines in order to get whatever electrical power supply may be necessary. In addition to the office and laboratory rooms, one large and attractive room has been set aside for the library which is being developed. The laboratory subscribes to 97 scientific and technical journals each year, and in addition has accumulated a large number of back volumes of the scientific and technical journals and a number of text-books on subjects of interest to the members of the laboratory and to those in the other departments of the association. The new Physical Laboratory building is heated

by hot-water heat, but as all the windows are double, in order to maintain constant temperature conditions, artificial ventilation is provided. With the view to avoiding any unnecessary vibration in the main laboratory building, the ventilating plant is placed in a small room separate from the laboratory building but connected with it by an underground tunnel. In this room is placed an air-washing system, with heating and tempering coils and blowers in order to supply warm, fresh air to the various rooms of the laboratory.

The instrument shop—a necessary adjunct to a physical research laboratory—is located in the basement of an adjoining building, connected by an underground tunnel with the ventilating plant room and with the main laboratory building. Adjacent to the instrument shop in the same basement are located the storage battery room and the power room. Electric power is supplied by the local lighting power company on a system of 440 volts, 3-phase, 60 cycles, which by the use of suitable motor generator sets is transformed into direct current for charging the storage battery and supplying other necessary power to the laboratory, and into alternating current of various frequencies and voltages for experimental use.

The personnel of the laboratory consists at present of the following:

Edw. P. Hyde, Ph.D., Director.
Francis E. Cady, B.S., Assistant to the Director.
Percy W. Cobb, A.B., M.D., Physiologist.
Charles F. Lorenz, Ph.D., Associate Physicist.
A. G. Worthing, Ph.D., Associate Physicist.
M. Luckiesh, A.M., Assistant Physicist.
H. M. Johnson, Ph.D., Assistant Psychologist.
(Vacant), Assistant Physicist.
One mechanician.
Two stenographers.
Three laboratory apprentices.
A total of fourteen persons.

The equipment of the laboratory, though not extravagant, is ample for all needs, and new apparatus is added from time to time as it is required for the proper conduct of the work of the laboratory. The instrument shop, in charge of a mechanician

of excellent training, is equipped with modern machines, all directly connected and electrically driven.

With this description of the personnel and physical equipment of the laboratory as an introduction, let us turn to the scientific work of the laboratory. It is perhaps not unnecessary repetition to state once again that the Physical Laboratory was organized primarily not for the development of the electric lamp, but for the development of the science of lighting, particularly those branches of the science of lighting which have, or may ultimately have, some bearing on the question of practical illumination. Some unimaginative persons find it difficult to understand why a commercial corporation should engage in what they term a philanthropic enterprise. To those nearsighted and unimaginative persons I would point out that, as in art and in science, so in business, the establishment and maintenance of high ideals is one of the necessary corollaries of complete and continued success.

The industry of incandescent lamp manufacture and the development of the uses of the incandescent lamp in illumination rest on the scientific development of the past generations. It is now a generally-recognized principle in modern business organization to establish a research laboratory for the development of the commercial commodity which is manufactured. But why is it not of equal, if of less immediate, importance to develop the pure sciences from which the practical industrial application must ultimately come? It has been said that inventions flourish best in an atmosphere that is dense with scientific research, and this, I think, is true of an organization as it is of a race.

The organization and development of the laboratory has, therefore, proceeded with this thought in mind: to extend our knowledge in the physics, physiology, and psychology of light, particularly in those phases of these sciences which pertain to the science of illumination. The fundamental idea which has prevailed is the proper co-ordination of physics, physiology, and psychology—the proper co-operation of the physicist, the physiologist, and the psychologist. The work of Helmholtz attests to the accomplishments of a proper co-ordination of physics and physiology. Unfortunately there was but one Helmholtz. Moreover, the domains of the widely-extended sciences of physics and physiology are ever broadening, and the possibility of the

happy combination of the physicist and the physiologist in one man is ever diminishing. The differentiation of the sciences must be accompanied by a co-operation of the scientists if the great middle fields of science are to be adequately covered.

The scheme of organization of the Physical Laboratory contemplates no sharp distinctions among the different divisions of the work, but the problems to be investigated group themselves roughly into three classes: (1) those which have to do with the production of luminous energy; (2) those which have to do with the utilization of luminous energy; and (3) those which have to do with the effects of luminous and attendant radiation. Under the first class comes the investigation of the laws of radiation and of the radiating properties of matter. The problems in this class are purely physical. Much progress has been made in the study of the phenomena and laws of radiation, but our knowledge in this field is still very meagre. Certain simple laws for the ideal complete radiator have been deduced as the result of theoretical and experimental investigation, but the values of the constants appearing in the corresponding equations are in many cases still in doubt, and even the form of the equation is not always agreed upon. Our knowledge of the deviation from the laws of the black body in the radiation of material substances is of most limited extent. The classification of matter on the basis of its radiating properties and the correlation of these properties with the other characteristic properties of matter have scarcely been attempted. Such a classification would be of the greatest scientific interest, and would be of invaluable benefit in the further development of the art of illumination.

Under the third class comes the investigation of the effects of light and of the attendant radiation on the eye, on the skin, and on microscopic organisms, and of those more subtle but equally important effects of light on our mental phenomena, such as attention, memory, and the emotions. Problems in this class are physiological and psychological. The corresponding division is under the charge of a well-trained experimental physiologist, with the assistance of a trained psychologist. The possibilities in this field of work are unlimited, but the obstacles in the way of conclusive results, particularly of the effect of light on the eye and on our mental phenomena, are unusually great, owing to the inherent difficulties in the experiment. Many of the

problems in this field, however, are rapidly being recognized the world over as vital to the welfare of the race.

Intermediate between these two classes of problems—those having to do with the physical production of radiation on the one hand, and those having to do with the physiological and psychological effects on the other—which are distinctly different, there is another which forms the connecting link. The problems of this class have to do with the absorbing, reflecting, and diffusing properties of matter, the measurement of light, *i.e.*, photometry, and the study of the complex phenomena of color and color sensation. The division of the work having to do with the study of these problems comes into closest contact with the actual problems in illuminating engineering practice. It serves as a medium by means of which the scientific results of the other divisions of the laboratory are correlated and applied in a scientific way to practical conditions. As stated previously, the organization of the work into these three divisions does not contemplate sharp lines of demarcation between them, but is intended to insure attention to all phases of the problem before us in order that the concomitant development of the different lines of investigation may conduce to the most valuable integral results.

The scheme of work for the laboratory was developed at the time of its inception, and now, some four years later, we look back over the results accomplished by the laboratory and measure these accomplishments against the standards set at the beginning. It should be remembered that, although the laboratory formally came into existence four years ago last October, the entire first year was consumed in securing laboratory facilities, apparatus, and collaborators. The larger portion of the succeeding year was required for the preparation and development of plans of work, so that the actual scientific work of the laboratory can be said to have begun in the early part of the year 1910, giving thus a period of about three years over which the scientific investigations have extended.

It will be helpful, in reviewing the work of the laboratory, to refer at this point to the first issue of the laboratory publication, which has been termed the *Abstract-Bulletin*. It has been the policy of the laboratory to present the results of the investigations carried out in the laboratory before the scientific and technical societies of this country, and to publish the finished papers in the

recognized scientific and technical journals of the United States and Europe. This has been done because it has seemed unwise to restrict the publications of these investigations to a new journal issued by the laboratory. The introduction of such a new journal would add one other to the already long list of scientific journals which must be subscribed for and read, and, even though there was a willingness on the part of scientific workers to add a new journal to those which they already must review, which is not the case, it would still be difficult to bring the results of the work of the laboratory before all who may be interested, because of the difficulty in securing a circulation comparable with that which has been developed gradually for many of the scientific journals now recognized and subscribed for throughout the civilized world.

But according to this plan of publication the results of the laboratory are distributed in scattered papers in many different journals, and, as it has seemed advisable that the complete work of the laboratory should be collated in such a way as to render it available to all who may be interested, the present *Abstract-Bulletin* is being published and distributed. This *Abstract-Bulletin* contains an abstract of every research carried out in the laboratory from its inception to the summer of 1912. The abstracts, written by the authors of the original papers, are fully illustrated with photographs and drawings, in the hope that to all except those who are especially interested in the details of the investigation they may be satisfactory substitutes for the original papers. If then, as a guide, we refer to the *Abstract-Bulletin* which contains results of all of the scientific work carried out in the laboratory up to the summer of 1912, it will only be necessary to add those investigations which may have been completed in the last six months in order to give a complete survey of the scientific activities of the laboratory in so far as they are concerned with original investigations.

By reference to the Table of Contents of the *Abstract-Bulletin* we find that 28 papers are abstracted in the first issue of the *Bulletin*. Of these 28 papers it will be found that nine or ten, or practically one-third of the total number of papers published, have to do with what has been termed the "physical production of light." Three or four papers have to do with the effects of light, and the remainder of the papers, or about one-

half of the total number published, have to do with problems in that intermediate field including photometry and physical questions in illuminating engineering. One problem of considerable interest and importance is the determination of the radiation from metals as a function of temperature. The question arises as to whether the radiation from tungsten or tantalum conforms, in its distribution in the spectrum, to that of a black body at the same temperature, or whether it shows a selectivity in favor of the visible spectrum. In other words, is the efficiency of the tungsten lamp entirely ascribable to its temperature of operation, or is it partially ascribable to a selectivity in its radiation?

The physics of the electric incandescent lamp furnishes an excellent field for investigation and is a logical point at which to begin an investigation of the radiating properties of matter, because of the simplicity of the problem compared with the more complex problem of the physics of the incandescent mantel. Inasmuch as the filament is operated electrically and there is very little, if any, interaction between the filament and the extremely small quantity of surrounding gas, it is much easier by measuring the electric power supplied to determine the total radiation from the filament. This latter question is one which has caused considerable difficulty, but which has been solved in the laboratory, the results of the investigation of this problem being published under the title "A Study of the Energy Losses in Electric Incandescent Lamps." It is very helpful, in studying the radiation of metals, to be able to measure accurately and easily the total energy radiated. This is very difficult to determine by any objective absolute method, but i comparatively simple of determination if we know the correction to be applied to the power supplied to a filament. We know that the total energy supplied to a filament is radiated except in so far as there is some loss by thermal conduction at the leading-in and anchoring wires. A method has been developed in the laboratory by which it is possible to determine accurately the amount of energy supplied per second to each element of length of the filament, the amount of energy radiated by each element of the filament, and the luminous value of the radiation from each element of the filament. In this way it is an easy matter to determine, from the energy supplied, the total radiation, applying a correction for the ends of the filament.

This study of the energy losses in electric lamps must be considered as auxiliary to the main problem in hand. In addition to the investigation of this problem, another auxiliary problem presented itself for investigation, viz., the determination of the correction which must be applied in spectro-photometric measurements owing to the impurity of the spectrum. It is known that if two continuous spectra, somewhat different in energy distribution, are intercompared by means of a spectro-photometer, the ratios obtained from the spectro-photometric settings do not represent accurately the relative distribution of energy in the two spectra, but that a correction must be applied. This problem has been investigated in the Physical Laboratory with considerable thoroughness from the theoretical standpoint, and the results have been tested and verified by experiment. In connection with this latter investigation a new form of variable rotating sectored disk for use with the spectro-photometer has been developed, and has been shown to be very satisfactory in actual operation.

Having completed these auxiliary investigations, attention was turned again to the main problem,—namely, that of the investigation of the radiating properties of matter—and a new determination was made of the selective radiation from tantalum. During the past year much work has been done on the radiation from metals following the line of attack initiated by the writer. The results of this work have been correlated and published in a paper entitled "The Synthetic Development of the Radiation Laws for Metals." As stated before, it must be remembered that the investigation of the radiating properties of matter was begun at the simplest point of attack—namely, with filaments of metal mounted in exhausted bulbs. It is the intention, however, to continue this work to the investigation of the radiating properties of other materials, such as the rare earth oxides as found in the incandescent mantle. The difficulties to be encountered in this work will be very much greater than those encountered in the study of the radiating properties of metals.

It is interesting to digress here from the consideration of papers abstracted in the *Abstract-Bulletin* to refer to some work that has recently been done, largely in continuation of the method used in studying energy losses in electric incandescent lamps. It was noticed by Dr. Worthing that the distribution of tempera-

ture along the two legs of a filament with respect to a point of support was different, and that the difference depended on the direction in which the current was flowing through the filament. By accurate measurement of these differences it has been found possible, through the use of a formula developed theoretically, to measure the Thomson electromotive force in metals at high temperatures, as these differences in distribution of temperature on the two sides of the anchor or support are unquestionably due to the operation of the Thomson electromotive force on one side in conjunction with, and on the other side in opposition to, the electric current. This investigation has been completed and the results have been published in abstract. The complete paper is now ready for publication, although no reference is made to it in the *Abstract-Bulletin*.

Another investigation which was carried out by Dr. Worthing, using in part the method which was used in studying the energy losses, was the study of Lambert's cosine law of emission for tungsten and carbon. It can readily be shown theoretically that for a black body the radiation emitted by a cm.^{2} of surface at any angle is equal to the radiation emitted normally, multiplied by the cosine of the angle between the normal direction and the direction in which the observation is made. It has usually been considered that for most ordinary substances the radiation at any angle is less than that computed on the basis of Lambert's cosine law. As the result of an investigation of this question by the new method Dr. Worthing has shown that in the case of carbon the deviation is in the ordinarily-accepted direction, but that in the case of tungsten the energy emitted at any angle up to 80 degrees or 85 degrees is larger than that which should be emitted on the basis of Lambert's law. A careful study showed that this deviation for tungsten increases from an angle slightly different from that of normal emission to an angle of 70 degrees or 75 degrees, where the deviation becomes as large as 15 per cent. Beyond this angle the emission falls off, and beyond 80 degrees or 85 degrees the deviation is in the direction ordinarily considered to hold, and which was found to hold uniformly for carbon. This investigation was completed some months ago, and has just appeared in the *Astrophysical Journal*, but it is not referred to in the *Abstract-Bulletin*.

Returning to the papers abstracted in the *Abstract-Bulletin*

and having to do with the production of light, one very important and thorough piece of work carried out by Dr. Ives and Mr. Luckiesh has been published under the title "The Effect of Red and Infra-red on the Decay of Phosphorescence in Zinc Sulphide." This investigation brings out some very interesting results on the relation between the time of decay and the shape of the decay curve in its relation to the effect of red and infra-red excitation. In addition to these more important lines of work on the physics of light production, one or two other pieces of investigation, such as a further study of the radiation from the firefly and the study of the ultra-violet radiation from common illuminants, have been carried out.

Passing now to the investigations having to do with the effects of luminous and attendant radiation, we find that the published papers on these subjects are not as numerous as those on some of the other more physical phases of the question. The reason for this is twofold. In the first place, it is necessary to spend more time in developing methods in this field of research, as the point of departure is new. In the second place, the organization of this division of the work has not been developed as rapidly as that of the other divisions. The investigation by Dr. Cobb on "The Influence of Illumination of the Eye on Visual Acuity" is to be mentioned. Another investigation bearing on a similar question by Mr. Luckiesh, of which mention should be made, is the investigation of "The Dependence of Visual Acuity on the Wavelength of Light." The problem of so-called "glare" is one of very great importance and interest, but it is one of great difficulty. The investigations by Dr. Cobb and Mr. Luckiesh on this subject constitute a beginning. Though not mentioned in the *Bulletin*, much more work has been done on this subject. Dr. Cobb, in conjunction with Dr. Geissler, formerly the psychologist of the laboratory, has carried out an elaborate investigation of the influence of the visual field on acuity and on the determination of the least perceptible difference. The results of this investigation have been presented recently before the American Association for the Advancement of Science, and will soon, I hope, be published in full. It is the intention to begin in the very near future an investigation which will have for its object the determination of the possible influence of glare,—*i.e.*, of an extraneous bright light in the field of view, on the muscular

control of the eye, on the nervous system, on circulation, and on other physiological processes subject to measurement,—in the hope of finding some immediate definite symptom of the deleterious effect of glaring light sources in the field of view. Other problems in physiological optics have been begun and are in part finished, but are not yet ready for presentation..

By far the largest number of papers abstracted in the *Bulletin* have to do with problems in that intermediate field more closely connected with the direct application in illumination. Especial attention is to be called to the classical work of Dr. Ives and Mr. Luckiesh on heterochromatic photometry and on the study of color. The limitation of time precludes the possibility of doing more than mentioning the titles of a few of these pieces of investigation to give one an idea of the extent and diversity of the problems investigated in this field. Among these may be mentioned: "Studies in the Photometry of Lights of Different Colors," "Note on Crova's Method of Heterochromatic Photometry," "Color Measurements of Illuminants—A *Résumé*," "Effect of Yellow Glass on the Efficiency of Incandescent Lamps," "Subtractive Production of Artificial Daylight."

It may be a matter of some historical interest to record here what, so far as I know, was the beginning of the investigation of color in artificial illumination, other than in the more or less academic way of determining the distribution of energy in the visible spectra of light sources, such as has been done, of course, for very many years. The first investigation of color in illumination was undertaken in connection with a test which was made on the installation of Moore tubes in the New York Post Office by the Photometric Section of the Bureau of Standards in June, 1908. A short time previous to this Mr. F. E. Ives had placed on the market his colorimeter, designed principally for determining the color of fabrics, papers, etc. In connection with the other tests which were made on the Moore tube in comparison with other installations it was suggested that a determination of the color value would be of interest, and an invitation extended to Mr. F. E. Ives to make such a test with his colorimeter was accepted. Unfortunately, owing to conditions more or less beyond our control, the results of this test were of very little direct value, but the indirect value has been accumulating ever since that time. Shortly afterwards Mr. Ives made more accurate

color measurements on the Moore tube, and subsequently Dr. Ives, at the Bureau of Standards, in connection with the work in photometry, undertook measurements on the Moore tube and on other light sources. Since that time numerous investigations have been made on color in artificial illumination, and at the present time this is one of the important elements which are taken into consideration in illumination installations and in tests made on such installations.

It is, of course, impossible in a limited time to review even in moderate detail the research work accomplished in the laboratory. Moreover, neither does time permit nor is this the place to discuss at length the activities of the laboratory in connection with the various engineering societies, the co-operation with which has been considered one of the valuable functions which the laboratory should perform.

In closing it may not be amiss to refer briefly to some of the plans of the laboratory for the future. First, it should be stated that there is no intention of altering seriously the general plan of organization that has been developed. On the other hand, it is hoped that this plan may develop still further, and that through co-operation more and more of the important problems which are on the border-line between physics, physiology, and psychology may be attacked and important results may be obtained. The physical work is fairly well organized at the present time, but even in this field the laboratory has been handicapped, owing to the lack of steady conditions for accurate sensitive galvanometer measurements, such as we hope to have available in the new laboratory. There is a vast field for investigation in the physiology and psychology of light—a field which has only been touched at the border. It is hoped that in this important line of research some of the difficulties will be overcome and methods will be developed which will yield results of some definite value.

The Physical Laboratory of the National Electric Lamp Association occupies a unique position among the laboratories of the world, and it is the hope and desire of those responsible for it and of all those associated with it that the laboratory may be made as useful as possible in developing the science of light in its relation to the science of lighting. To this end we are ever awake to suggestions that may enhance the value of its contributions. One plan which is at present under consideration is that of

possibly opening the doors of the laboratory to a limited number of advanced students and members of university faculties to undertake research work on subjects correlated with those in which the laboratory is interested and under conditions most favorable for those investigations. It is thus hoped that it may be possible to open a few rooms in the laboratory to advanced students in physics who desire to carry out research work under conditions where the value of the application in the industries is appreciated, so that the laboratory may partially assist in supplying a want which would seem to exist at the present time. There seems to be no reason why there should not be as great a demand for physicists in the industries as there is for chemists, and I am of the opinion that this is due, at least partially, to the lack of development of physicists appreciative of the atmosphere which prevails in industrial work.

In a somewhat similar way, if I am correctly informed, there is need of research work by ophthalmologists on questions pertaining to the relation of light and other radiations on vision. I am told that very little research work in ophthalmology is being done in this country, and that that which is being done is confined principally to the pathology of the eye. It has been suggested to me that possibly it might be of value to open a room of the laboratory for an investigator in some problems that are ophthalmological in their results but which require physical and physiological apparatus and facilities in order to be properly carried out. In every department of the laboratory's activities we would be grateful for suggestions and criticisms in order that the laboratory may fulfil its mission to the highest possible degree.

As has been said, the principal object of the Physical Laboratory of the National Electric Lamp Association is not invention or the development of the electric incandescent lamp, but rather the development of the science of light in its relation to the science of illumination. It is, however, the hope and expectation of some of us connected with this laboratory that there may grow up and develop, co-ordinate with but distinct from the division for pure research, a separate division on industrial physics which shall be organized primarily for the practical development of illumination methods and of the incandescent lamp. There would then be in one organization the complete cycle of activity, beginning with the development of pure science

and ending with the sale of a commercial commodity. The motto of the Physical Laboratory, inscribed over the portal of the new building, is "*Veritas vos Liberabit,*" but in order that the truth shall make us free it is necessary that the truth shall be propagated and that the truth shall be applied.

It seems peculiarly fitting to-night, in this Institute founded as an appropriate memorial to that illustrious scientist, who at the same time was keenly appreciative of the application of science in the arts, that here to-night I should present to the members and friends of the Franklin Institute the results, meagre though they be, of the first laboratory in the world, so far as I know, organized and supported by a commercial organization for the development of pure science. If Benjamin Franklin were here to-night I am sure that his heart would glow with joy and satisfaction at the thought that the United States was fulfilling in the most complete and highest sense its destiny as the first industrial nation of the world. Those of us who are responsible for the results accomplished by the Physical Laboratory of the National Electric Lamp Association are keenly appreciative of the unusual responsibility devolving upon us, for in my judgment an element of positive worth in the progress of civilization will have been destroyed if this first experiment is unsuccessful and the principle underlying it is inferred to be fallacious. It is therefore hoped that the friendly criticism and advice of those who are in sympathy with the idea underlying the organization and purpose of the laboratory may be given, to the end that the laboratory may realize its ideals and that the principle of the organization and support by a commercial organization of a laboratory for pure science may be established as sound in theory, practicable in operation, and valuable in results.

Corrosion Test of Monel Metal. ANON. (*Foundry*, xl, 505.)—The New York Board of Water Supply made corrosion tests on several metals by burying samples in the earth for six months, and periodically wetting the earth with dilute solutions of corrosive salts. The losses were: phosphor bronze 0.09 per cent., Tobin bronze 0.11, monel metal 0.12, manganese bronze 0.12, Muntz metal 0.33, and steel 1.04 per cent. The monel metal made the best appearance of all after the test.

Kambara Earth: A Decolorizing Material for Mineral Oils, Etc. K. KOBAYASHI. (*J. Ind. Eng. Chem.*, iv, 891.)—Kambara earth is from the Echigo province of Japan and belongs to the same class of fuller's earth as that found in Florida, but is more efficient. It resembles hard wax, feels soapy, has detergent properties, and is dissociated by and miscible with water. It consists of fine particles of earth without any admixture of quartz. Its contents are: silica 60.71 per cent., aluminum oxide 13.18, iron oxide 3.68, calcium oxide 0.62, magnesium oxide 0.38, sodium and potassium oxides 1.54, and loss on ignition 20.04 per cent. It is essentially composed of hydrates of silicic acid and aluminum silicates. Numerous experiments on its action with dyes are recorded. With crude petroleums it absorbs the unsaturated hydro-carbons. It removes certain impurities from methyl alcohol, and tar from pyroligneous acid. The earth is slightly acid, and is thus distinguished from ordinary kaolin and clay, and probably some of its efficiency is due to this acidity.

Use of Mica as an Insulator. F. WIGGINS. (*Elec. Rev.*, lxxi, 564.)—Mica can be obtained in sizes up to 24 inches by 12 inches. The limitations of micanite are pointed out, but the quality depends largely on the price paid. Pure mica tubes, consisting entirely of rolled mica without any cement, can be obtained up to 12 inches or 18 inches in length, and, as they can be used much thinner than the micanite tubes, the increased cost is not so large as might appear at first sight. Hints are given as to the splitting and working of mica, which requires care and experience.

Dangers of Coal. M. DENNSTEDT and L. SCHAFER. (*Zeit. Angew. Chem.*, xxv, 2625.)—Commences by describing an apparatus and a method by which coals may be tested and classified as regards their liability to self-ignition. Such tests would furnish definite data as to the safety or danger of storing and transporting any particular type of coals. Coals which when heated to 150° C. in a stream of oxygen show no tendency to increase of temperature are absolutely safe; those which show a slight tendency to heat up locally but fail to ignite within an hour are safe enough for storing and transporting on board ship. Those which ignite within an hour and below 150° C. are relatively dangerous coals. The temperature of self-ignition, and the time of heating necessary, determine relatively the degree of danger. In general the heat value of the coal is not an index as to its tendency to self-ignition; brown coals are much more dangerous in this respect than soft coals. The presence of finely-divided particles in a coal pile increase this danger greatly. The coals tested show that the greater the percentage of oxygen in the coal the greater the liability to self-ignition.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

WEIGHTS AND MEASURES CONFERENCE.

AMONG the important legislation reported upon by the secretary of the recent Weights and Measures Conference at the Bureau of Standards there were two national laws: The first was an act to establish a standard barrel and standard grades for apples when packed in barrels, which was approved August 3, 1912. "This act does not prevent the shipment in interstate commerce of either inferior apples or of apples packed in short barrels if they are not marked so as to bring them under the law. It merely provides that if apples are sold and marked to conform with the regulations of the act, they must be packed in the standard barrel and be of specified quality and size."

The other is an act of far-reaching importance in the amendment to the Food and Drugs Act, which requires that all food for interstate shipment put up in package form must have the net contents plainly and conspicuously marked on the outside of the package in terms of weight, measure, or numerical count, provided that reasonable variations shall be permitted and tolerances and exemptions as to small packages shall be established by rules and regulations made by the Secretary of the Treasury, the Secretary of Agriculture, and the Secretary of Commerce.

A board representing the three Secretaries is at present engaged in drawing up the rules and regulations for the enforcement of this act. This act has wide application in connection with the enforcement of the national Food and Drugs Act and similar acts passed by the various States.

This decision, in substance, is that the States can not adopt regulations which are in conflict with those made or adopted under the authority of Congress.

The activity in the States in regard to weights and measures legislation reported on at the last meeting has been continued this year, the following named States having passed laws on the subject of weights and measures: Arizona, Idaho, Indiana, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minn-

* Communicated by the Bureau.

esota, Nebraska, New Hampshire, New Jersey, New Mexico, New York, Ohio, Oregon, Pennsylvania, South Carolina, Virginia, Vermont, and Washington. Quite a number of other States considered bills, and the prospects are encouraging for considerable progress at the next legislative sessions.

The conference has long been in favor of the passage of a law to establish a standard barrel for all dry commodities shipped from one State to another. Such bill was introduced into Congress at its last session.

THE TESTING OF CAPACITY MEASURES.*

By R. Y. Ferner,

Bureau of Standards.

THIS paper describes the methods used for determinations of the volume of capacity measures, varying from the precision test of high-grade primary standards for State governments to the rough determinations by linear measurements of the dimensions of the measure. The precision test is applied to measures used as standards by State and city sealers of weights and measures and as master measures in manufacturing plants. The determination is made by weighing the amount of water contained in the measure, and from tables of water weights the correction of the measure is determined. Precautions to be observed in the filling and weighing of the measure are noted, and tables and charts are given for the rapid computation of the results. The method can be used to an accuracy of from one part in 50,000 to one in 100,000. Factors that may be omitted in the application of this method where less accuracy is required are pointed out.

For determinations to an accuracy of from one part in 500 to one in 1000 the method of pouring water from a standard to the measure under test is used, and precautions to be observed in the manipulation are given. For the test of rougher measures, particularly of dry measures which will not hold water, tests are made with seeds as a medium. Results are given of a series of experiments made to determine which kinds of seeds are the best for this purpose. For the smaller measures the small

* A paper read at the Eighth Annual Conference on Weights and Measures, held at the Bureau of Standards, May 14-17, 1913.

spherical seed called rape seed proved to be much better than the commonly used flaxseed, while for larger measures dried peas are recommended. The effects of varying heights of fall of the seed, of shaking down or jarring the seed during the test, and of different methods of striking off the surplus seed are discussed. Results varying from one part in 100 to one in 400 may be obtained by this method. Finally the various gauges on the market for determining the accuracy of measures, particularly dry measures, by measurements of their dimensions are described, and simple formulæ are given for the rapid computation of the volume of measures by the linear dimensions. Results by this method vary in accuracy from 2 per cent. to 0.5 per cent.

ELECTROLYTIC CORROSION OF IRON IN SOILS.*

By Burton McCollum and K. H. Logan.

THIS is an experimental paper dealing with the fundamental laws governing electrolytic corrosion of iron imbedded in soils. The results are expressed in terms of electrolytic corrosion efficiency. If the corrosion of the anode is the sole reaction involved at the anode, then according to Faraday's law 96,540 coulombs are required to corrode one gramme-equivalent of the metal, and the corrosion efficiency is said to be 100 per cent. In most cases, however, the actual corrosion noted is either greater or less than this amount, and the percentage which the actual corrosion in any case is of the theoretical amount is called the efficiency of electrolytic corrosion. The experimental data presented in the paper show how the efficiency of corrosion is affected by the varying physical conditions encountered in practice. It is found that current density has a marked effect on the efficiency corrosion of iron in soils, the efficiency being in general greater the lower the current density. In saturated soils efficiency of corrosion may vary between 20 per cent., and about 140 per cent., for the range of current densities between 5 milliamperes and .05 milliampere per square centimetre. Moisture content in the soil also has a marked effect on efficiency of corrosion, the corrosion being in general greater with increasing moisture content up to saturation of the soil.

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* Technologic Paper No. 25, Bureau of Standards.

Temperature changes within the limits commonly met with in practice, the amounts of oxygen present in the soil, and the depth of burial of pipes below the surface have no material effect on corrosion efficiency. The voltage impressed on the electrodes likewise has no material effect on the corrosion efficiency except in so far as the current density may be affected.

The pitting of iron imbedded in soils is found to be affected not only by a non-homogenous condition of the iron itself, but also by the chemicals contained in the soils; certain chemicals, such as nitrate, for example, give rise to comparatively uniform corrosion, whereas certain others, particularly chlorides, produce much greater pitting effects.

While it is found that the amount of oxygen present has no appreciable effect on the corrosion efficiency, it does affect in a marked degree the character of the end products formed. If the corrosion is rapid and the supply of oxygen small there will be a preponderance of magnetic oxide, while if the rate of corrosion is slow and the supply of oxygen abundant, the ferric oxide will predominate. Owing to the fact that the supply of oxygen around the pipes buried in earth is always more or less limited the character of the oxides formed gives some indication as to the rate of corrosion, and thus indirectly the cause of the corrosion if local conditions are properly considered.

There is no material difference in the efficiency of corrosion shown by the various kinds of iron commonly used in the manufacture of underground pipes so long as physical conditions are similar. In actual practice, however, wide variations of corrosion in all kinds of iron may be expected, and the results of a large number of tests show that under most practical conditions the corrosion efficiencies will range between 50 and 110 per cent.

The paper also gives a great deal of data on the subject of the resistance of soils and its variation with temperature, moisture content, and other physical conditions, and discusses the relation between these resistance changes and stray current electrolysis.

THE Bureau of Standards will shortly issue the Technologic Paper No. 14 on "Legal Specifications for Illuminating Gas," which is a brief discussion of the recommendations made by this Bureau for State or city laws to control the quality of illuminating gas sold.

The Bureau undertook several years ago an investigation of calorimetric standards and of flame standards for gas photometry, but as the work progressed it became evident that other phases of gas testing were equally deserving of attention, and the field of the investigation was therefore extended to include all gas-testing work.

As the heating value of a gas is a better measure of its usefulness for power, heating, or lighting with mantles than is the candle-power of the gas, the heat delivered to customers should be measured and controlled in order to insure good service. For open-flame lights only, the candle-power must be maintained. As many persons still use such burners, even though they are less economical than a mantle, the candle-power can not be entirely overlooked. The Bureau of Standards proposes that a secondary requirement be fixed by cities to insure sufficient candle-power of the gas for this use, and that the heating value be made the principal basis of gas rating.

The basis of rating of the gas and its purity are also discussed in this paper. Copies may be had by addressing the Bureau of Standards, Department of Commerce, Washington, D. C., referring to Technologic Paper No. 14.

THE FUNCTION OF TIME IN THE VITRIFICATION OF CLAY.

THE Bureau of Standards is sending to press Technologic Paper No. 17 upon the function of time in the vitrification of clay. The paper is a study of six clays which were heated to their maturing temperatures at definite rates and comparing the heat effect by means of porosity and shrinkage determination.

Time is an exceedingly important factor in the maturing of clays and bodies. A certain result may be obtained either by the use of a higher temperature for a shorter time or a lower temperature for a longer time. This fact we see constantly illustrated in the firing of all kinds of clay products, the melting of glass, the softening of pyrometric cones, etc. Yet there are definite thermal limits to which such relations are confined. These correspond to the lowest temperature at which partial softening, which is a necessary condition of vitrification, can take place.

The effect of the time-temperature relations should be studied closely for every clay, since only when reliable information concerning this subject is at hand is it possible to exercise complete control of the burning. The importance of such results applied in factory practice cannot be emphasized too much.

The use of pyrometers in plant operation is to be urged most strongly, as they afford the only means of controlling the rate of firing. For the establishment of the end point of the burned pyrometric cones, shrinkage and porosity determinations are of value.

In the use of cones the time factor should be taken into account.

Wood, Paper, and Steel Pulleys. H. A. WOODWORTH. (*Power*, xxxvi, 848.)—Woodworth and E. D. Biggs made tests at Purdue University to determine the breaking strength of pulleys of different materials with the object of ascertaining their principal points of weakness. Mechanical engineers will find these very interesting. Some of the conclusions arrived at are: (1) Rim joints midway between arms are serious defects and materially reduce the bursting speed. (2) The solid-web-and-rim paper flywheel will safely withstand a peripheral speed of 106 feet per second. (3) Wood flywheels with solid rims have an ample factor of safety at a peripheral speed of 90 feet per second, if the wood is of good quality. (4) Steel wheels of the split-rim type are unsafe at speeds above 80 feet per second.

Special Rails for Heavy Curves and Grades of the Lehigh Valley Railroad. ANON. (*Eng. News*, lxviii, 779.)—The use of specially heavy rails on sharp curves and steep grades, where conditions of rail wear are severe, is being successfully introduced by the Lehigh Valley Railroad. The rail is a 110-pound section of the same height and base width as the 100-pound standard, but with a heavier web, $^{19}/_{32}$ inch instead of $^{9}/_{16}$ inch; and a larger and much deeper head, $1\frac{7}{8}$ inches deep instead of $1^{9}/_{16}$ inches. A six-bolt joint is used, but the outside splice bar is of special design, extending along the side of the rail head to secure additional depth and rigidity. A section of the 110-pound rail and its splice joint, with the head of the 100-pound rail shown in dotted lines, is given. There are at present about 77 miles of track laid with the 110-pound rail, and additional rails in process of laying will bring the total to about 100 miles. A compromise joint is used to connect rails of the two forms of section, the tops being stepped to fit the different heights of web and head.

THE FRANKLIN INSTITUTE

AWARD OF THE ELLIOTT CRESSON MEDAL TO DISTINGUISHED SCIENTISTS AND TECHNOLOGISTS.

To the roll of distinguished scientists and technologists who have received from THE FRANKLIN INSTITUTE its Elliott Cresson Medal—the highest recognition in its gift—have been added* the names of Lord Rayleigh, Sir William Ramsay, Prof. Dr. Emil Fischer, Dr. Charles P. Steinmetz, and M. Emile Berliner.

Mr. Berliner, Dr. Randolph and Dr. Steinmetz were present at the Stated Meeting of the Institute on the evening of Wednesday, May 21, and received the medals awarded them from the President of the Institute, Dr. Walton Clark.

They were presented by Dr. Harry F. Keller.

In presenting Mr. Berliner, Dr. Keller said:

"MR. PRESIDENT: The Committee on Science and the Arts has again assigned to me the most agreeable duty, or rather conferred upon me the privilege, of presenting to you the distinguished scientists and inventors whom The Franklin Institute desires to honor by the award of the highest recognition at its command, the Elliott Cresson Medal, and who are honoring the Institute by personally appearing at this meeting to receive it from your hands.

"A recent writer in one of our scientific magazines, in commenting upon the wonders of the modern world, calls attention to the fact that most of the great inventions and achievements are the results, not of the labors of individuals, but rather of some general element of modern progress. While it cannot be denied that this is true of the majority of scientific discoveries, useful inventions, and engineering feats, it must also be conceded that in nearly every instance the culminating achievement can be connected with one or a few great names.

"Thus one of the most marvellous of modern inventions, the one that received the second largest number of votes in an international ballot on "The Seven Wonders of the Modern World"—I refer to the telephone—was not the practical and useful device it is to-day when it first came from the

* See last issue of this JOURNAL, page 655.

hands of its inventor, but had to be modified and improved by others before it was universally introduced as an indispensable means of communication.

"A year ago The Franklin Institute awarded the Elliott Cresson Medal to Alexander Graham Bell, to whom undoubtedly belongs the honor of having solved the problem of the electrical transmission of articulate sounds, and of constructing the first speaking telephone. But at the very time when the award was made your Committee on Awards was considering the fitness of bestowing a similar recognition upon another pioneer in the transmission of speech and an inventor who more than any other has helped to make Professor Bell's great invention the perfect instrument to which we are accustomed.

"Born and educated in Germany, he came to this country in 1870, and after engaging in mercantile pursuits for several years he devoted his attention to the problems of the electrical transmission of speech. In 1877, the year after Bell had exhibited his telephone at the Centennial Exhibition in this city, he invented the loose-contact transmitter bearing his name, and which brought the telephone within the range of practical use and commercial application. Shortly afterward he effected another great advance in telephony by the use of the induction coil to step-up the low tension variable current through the loose-contact transmitter to a higher tension variable current in order to overcome the impedance of long lines.

"When, in 1878, the Bell Telephone Company was formed, he was appointed chief inspector at its works in Boston, and the first twenty thousand transmitters that went into use passed through his hands. In his capacity and later, as consulting expert to the Bell Telephone Company, he brought out and patented many other inventions relating to the telephone art.

"In the meantime he took up the improvement of the talking machine. In 1887 he invented the gramophone, which was the first talking machine that employed a record with a groove of even depth and varying direction, and in which the groove not only vibrates the recording stylus but also propels it. The device was exhibited by the inventor before The Franklin Institute in 1888, and on its recommendation the John Scott Medal was awarded to him by the city of Philadelphia.

"Under various trade names—the 'Victor' Talking Machine, for instance—the gramophone has achieved universal popularity and become the basis of a great and growing industry. It carries entertainment, instruction, and culture to the homes and the masses of the people of every country and clime, and it has in a very marked degree promoted and spread the appreciation of high-class music.

"Our medallist's inventions have by no means been confined to applications of electricity; he has also made notable and valuable improvements in the construction of motors and other devices used in aëroplanes. In recent years he has given much thought and attention to the pathology of milk, and his educational campaign on this subject has been fruitful of beneficial results in the interest of public hygiene.

The distinguished electrical engineer, the resourceful inventor, and the philanthropist who has accomplished all these things and many more that

I cannot enumerate for lack of time, I have the honor to introduce to you, Mr. President, as Mr. Emile Berliner, of Washington, D. C."

In presenting Dr. Randolph:

"MR. PRESIDENT: There is, perhaps, no better proof of the wide usefulness of this Franklin Institute, and of the high esteem in which it is held, than the fact that most of the American recipients of the Elliott Cresson Medal have at one time or another, and in many cases repeatedly, come here to address our meetings, either to exhibit and explain discoveries or inventions they have made, or to discuss those subjects in which they have been particularly interested or active. Thus only recently one of the foremost civil engineers which our country has produced and who is to receive that medal here to-night, addressed us in this hall in a most illuminating and inspiring manner on the theme "The Engineer in the Building of the Republic." The address was published in the March number of our JOURNAL, and it so well describes men who, like its author, have had a hand in the building of this Republic of ours, that I feel it would be impossible to introduce him better than by quoting his own eloquent words: 'What manner of man is he? Physically, like King Saul of old, he may stand head and shoulders above the people; he may be a man of brawn and sinew, or he may be frail and dapper, but in either case he will have the gift of continuance; he will set out to reach a goal, and no matter what obstacles lie in his path, he will reach it.

"'He endures hardship like a good soldier; summer's heat and winter's cold try his endurance, but he endures. He traverses rough places of the earth with an assured tread; his path is in the wilderness, and the solitary places know his footfall. If hunger overtakes him, he tightens his belt and still endures; thirst parches his tongue, but there are water springs, and he endures until their cooling draughts refresh him. The physical man is dominated by the intellectuality which dwells within him. Engineering is a science far-reaching and many-sided, dealing with the forces of Nature in all their varied forms and combinations. This man of whom we are talking, perhaps—we may say assuredly—has not mastered this science in all its branches, but he has chosen the division of that science to which he will devote his energies, physical and mental and *that* he knows. He may have acquired that knowledge within college walls, and his *alma mater* may be dear to him, or he may have acquired what he knows in the hard school of experience, ending up days of toil with nights of study, that he may know the reason for the things he has been doing or be ready to meet the problems that he knows lie ahead of him. He has more or less of the constructive instinct. He is a dreamer who can shut his eyes and see the things he means to create take outline and form upon the trestle-board of the imagination. Or he maps in relief the territory over which he has tramped and selects upon the wrinkled face of Nature those furrows through which he will carry the roadway, excavate his canal, or across which he will build his dam.' Such is the man whose great and brilliant achievements in engineering The Franklin

Institute desires to crown with its highest award. Born at New Market, Virginia, he acquired his education 'in the hard school of experience.' At the age of 20 he entered the service of the Baltimore & Ohio Railroad, and, rapidly advancing in his profession, he for many years devoted his energies to railroad engineering, acquiring a most varied and extended experience in the building of roads, freight-houses, and terminals. Since 1886 he has been engaged in general engineering work, and he has served as consulting and directing engineer in the carrying out of many projects of the first magnitude. Among these should be especially mentioned the construction of the great Sanitary and Ship Canal for the city of Chicago, his service under President Roosevelt on the Board of Consulting Engineers for the Panama Canal, the harbor improvements of Milwaukee, and the planning of the Deep Waterway from Lockport to Utica, but to enumerate all, even of his more important achievements, would take up much more time than is allotted to me.

"Mr. President, I have the honor to present to you Dr. Isham Randolph, of Chicago."

In presenting Dr. Steinmetz:

"MR. PRESIDENT: Last but not least of the trio of intellectual giants whom to pay homage to we have gathered here to-night is a man whose great achievements may not appeal to the popular understanding to the same extent as do those of the other two medallists. His name is not associated with any popular inventions or mentioned as that of the originator of great engineering feats; nevertheless, his wonderful intellect and ability have made him a leader in the development of that most useful of the wonders of the modern world, electricity. His chosen field is the mathematics and theory of electricity, and there is probably no branch of human activity in which mathematics—the higher mathematics—and theory have a more direct bearing upon practical results than in electrical engineering. Like his *confrère,* Mr. Berliner, he was born and educated in Germany. He received his training in the sciences and in mechanical engineering at the University of Breslau and the Zurich Polytechnikum; but his practical experience and a field for exercising his extraordinary abilities he found in our country, to which he came at the age of 24. The biographical sketch prepared by the Committee of Awards does not indicate that his life here has been an eventful one in the accepted sense of the term. His first position in this country was that of a draughtsman with the Eickemeyer Manufacturing Company, in whose employ he remained as electrical engineer and constructor, and then as Director of its Research Laboratory, until the Eickemeyer interests were absorbed by the General Electric Company, when he accepted a position in the calculating department of this largest corporation of its kind. When the headquarters of the company were transferred from Lynn, Mass., to Schenectady, N. Y., in 1894, he was given charge of the calculation and design of the company's apparatus, as well as of the research and development work. In 1902 he was called to

the chair of Electrical Engineering in Union University, still retaining, however, his connection with the General Electric Company as consulting engineer. In 1911 he organized and assumed charge of its Consulting Electrical Department.

"His constructive work has greatly advanced the electrical art, and special mention must be made of his improvements in alternating current motors, generators, converters, regulators and lighting.

"He has written a great number of books, papers, and addresses upon mathematical, engineering, and scientific subjects. His text-books and treatises are recognized as standard works, and his papers embody the results of the profoundest study and reasoning. Two years ago he stood before an audience in this venerable hall and conducted his listeners into "Some Unexplored Fields of Electrical Engineering."

"We may rest assured that such fields cannot long remain unexplored when they are entered by so penetrating, brilliant, and disciplined a mind as that of this investigator, Dr. Charles Proteus Steinmetz."

Brief biographical sketches of this year's recipients of the Elliott Cresson Medal are given below.

LORD RAYLEIGH, J.P., D.C.L., LL.D., F.R.S., Hon. C.E., Sc.D.

JOHN WILLIAM STRUTT, third Baron Rayleigh, was born in Essex on November 12, 1842. He was educated at Trinity College, Cambridge, from which he was graduated as senior wrangler in 1865, obtaining the first Smith's prize of the year.

From 1879 to 1884 he was Cavendish Professor of Experimental Physics at the University of Cambridge; and in 1887 he accepted the post of professor of natural philosophy at the Royal Institution of Great Britain, which he resigned in 1905. From 1887 to 1896 he was Secretary to the Royal Society. From 1892 to 1901 he was Lord Lieutenant of Essex. In 1905 he became president of the Royal Society, retaining this office till 1908, in which year he was chosen to succeed the eighth Duke of Devonshire as Chancellor of Cambridge University.

Lord Rayleigh's early mathematical and physical papers, written under the name of J. W. Strutt, made him known throughout Europe.

A great part of his theoretical work has consisted in reinvestigating familiar subjects and elaborating their respective data into precision. In this way he has gone over a great portion of the field of physics, and in many cases has either brought the investigation to finality for the time being, or else started new and fruitful developments. The various branches of chemical physics, particularly capillarity and viscosity, theory of gases, flow of liquids, photography, optics, color vision, wave theory, electric and magnetic problems, electrical measurements, elasticity, sound and hydrodynamics, have especially felt his influence.

The numerous scientific memoirs in which his original work is set forth were collected under his own editorship in four large volumes, the last of which was published in 1903. His most extensive work is a book on "Theory of Sound," which, in the second edition, has become a treatise on vibrations in general.

As the outcome of a long series of delicate weighings and much experimental care in the determination of the relative density of nitrogen gas, he made, in collaboration with Sir William Ramsay, the discovery of argon.

He has taken much interest in abnormal psychological investigations, and became a member and vice-president of the Society for Psychical Research.

Lord Rayleigh was one of the original members of the Order of Merit, instituted in connection with the coronation of King Edward VII. He is a past president of the Royal Society and Nobel laureate, having been awarded a Nobel prize in 1904. He is an officer of the Legion of Honour.

SIR WILLIAM RAMSAY, K.C.B., LL.D., D.Sc., M.D., Ph.D., F.R.S., F.C.S.

SIR WILLIAM RAMSAY was born in Glasgow on October 2, 1852. In his fourteenth year he matriculated at Glasgow University and there commenced his studies in chemistry, first under Sir William Thomson and then under Tatlock, and appears to have distinguished himself so decidedly that the latter often made him his deputy.

In 1870 Sir William continued his studies in Germany, passing one term with Bunsen and then moving to Fittig's laboratory at Tübingen. He was there inducted into the usual methods and problems of organic chemistry.

In 1872 he returned to his native city and was for two years laboratory assistant in the Young Laboratory of Chemistry, at Anderson's College. He was then appointed Tutorial Assistant of Chemistry in Glasgow University, a position which he held for six years. He there acquired a very extensive and profound knowledge of the whole field of chemistry, especially of inorganic chemistry.

In 1880 he was appointed to the chair of chemistry at University College, Bristol, and a year later he was made principal of the college. He continued at Bristol until 1887, when he was appointed to the highly-esteemed chair of chemistry at University College, London.

At this point began that rapid succession of researches which brought Sir William to scientific eminence. The measurements of surface tensions up to the critical temperature led to the well-known law which allows us to determine molecular weights in liquids. His work with Lord Rayleigh on the solution of the problem concerning the difference in density between atmospheric nitrogen and that obtained from compounds led to the discovery of argon in 1897. The periodic law immediately suggested

the existence of a number of other elements of the same type, and Sir William succeeded in a short time in discovering helium. Three further elements of the same group—neon, krypton and xenon—were afterward discovered by Sir William, associated with Morris William Travers.

As the result of an investigation taken up by him, following Becquerel's discovery of the dark rays of uranium, Sir William made his greatest discovery—that of the apparent transmutation of one element into another. The gaseous emanation of radium, which at first had behaved as an entirely new body, showed after some time the lines of helium, and, finally, it was definitely proved that radium in its spontaneous decomposition produced helium in a perfectly regular way.

Following this up, Sir William originated a series of other investigations, some of which are not yet completed, but which may be expected to result in further achievements of a high order.

Sir William is the author of numerous publications and papers. Some of the most important of these are:

"The Molecular Surface-Energy of Liquids."

"Argon, a New Constituent of the Atmosphere" (in conjunction with Lord Rayleigh).

"Helium, a Constituent of Certain Minerals."

"Neon, Krypton, and Xenon."

"The Transmutation of Radium into Helium" (with Mr. F. Soddy).

"The Discovery of the Constituents of the Air."

Three Text-books on Chemistry.

Many academic honors and various orders of distinction have been conferred upon Sir William Ramsay in recognition of his brilliant discoveries in chemistry. Among the orders are those of the Commander of the Crown of Italy; Officier de la Legion d'Honneur; Corresponding Member of the Institute of France; Hon. Member Royal Academies of Ireland, Berlin, Bohemia, Holland, Rome, St. Petersburg, etc.

Sir William is a member of numerous learned and scientific societies, among them being the German Chemical Society; American Philosophical Society, Pharmaceutical Society; Philosophical Societies of Manchester, and Rotterdam.

He was created K.C.B. in 1902, and in 1904 he was awarded the Nobel prize for his chemical researches.

EMIL FISCHER, Ph.D., M.D., Ing.D.Sc., F.R.S.

EMIL FISCHER was born at Euskirchen, in Rhenish Prussia, on October 9, 1852. After studying chemistry at Bonn, he went to Strassburg, where he was graduated Ph.D. in 1874. He then acted as assistant to Adolph von Baeyer for eight years, after which he was appointed to the chair of

chemistry successively at Erlangen (1882) and Würzburg (1885). In 1892 he succeeded A. W. von Hoffmann as professor of chemistry at Berlin.

Dr. Fischer devoted himself entirely to organic chemistry, and in 1875, the year following his engagement with von Baeyer, he published his discovery of the organic derivatives of a new compound of hydrogen and nitrogen, which he named hydrazine. He investigated both the aromatic and aliphatic derivatives, establishing their relation to the diazo compounds, and perceiving the readiness with which they entered into combination with other substances, he originated a large number of hitherto unknown compounds; including particularly the hydrozones, which result from the interaction of the aldehydes and ketones. His observations, published in 1886, that such hydrozones, by treatment with hydrochloric acid and zinc chloride, yielded derivatives of indol, the pyrrol of the benzene series and the parent substance of indigo, were a confirmation of the views advanced by his master, von Baeyer.

His further discovery was that phenyl hydrazine reacted with the sugars to form substances which he named osazones, and which, being highly crystalline and readily formed, served to identify such carbohydrates more definitely than had been previously possible.

Turning his attention to the rosaniline dyestuffs, he published papers in 1878 to 1879 which established that these dyestuffs were derivatives of triphenyl methane.

His next research was with compounds related to uric acid. In 1881–2 he published papers establishing the formulæ of uric acid, xanthine, caffeine, etc. In 1894 he commenced the publication of that notable series of papers wherein these compounds were all referred to a common base, purin. Concurrently, he took up the investigation of the sugar group and became the recognized pioneer in this field of investigation. Dr. Fischer synthesized fructose, glucose, etc., and prepared several stereoisomerides, completing a brilliant experimental research and confirming Van't Hoff's theory of the asymmetric carbon atom. As an outcome of his study of the sugars, he attacked the problem presented by ferments and enzymes. In this connection he discovered that the chemical constitution of a sugar is related to that of the ferment and enzyme which breaks it down.

He entered on perhaps his greatest work when he commenced the study of the chemistry of the proteins. By the introduction of new methods, Dr. Fischer succeeded in breaking down the complex albuminoid substances into amino acids and other nitrogenous compounds, the constitution of most of which have been solved. By bringing about the recombination of these units appropriately chosen, he prepared synthetic peptides which approximate to the natural products.

His publications include his "Untersuchungen über Aminosäuren, Polypeptide and Proteine;" "Untersuchungen in der Purin Gruppe;" "Untersuchungen über Kohlenhydrate und Fermente."

He was awarded the Nobel Prize for chemistry in 1902.

CHARLES PROTEUS STEINMETZ, A.M., Ph.D.

DR. CHARLES PROTEUS STEINMETZ was born April 9, 1865, at Breslau, Germany. He was educated at the Breslau Gymnasium and University, studying mathematics, astronomy, physics, chemistry, and other branches including economics. In Switzerland he studied mechanical engineering at the Polytechnicum of Zurich. In 1889 he came to America, and found a position with the Eickemeyer-Field Manufacturing Company, first as draftsman, then as electrical engineer and designer, and finally on research work in charge of the Eickemeyer Laboratory. With the absorption of the Eickemeyer interests by the General Electric Company, Dr. Steinmetz was attached to Mr. H. Parshall's calculating department in Lynn, Mass. When the company's headquarters were transferred to Schenectady, N. Y., in the spring of 1894, he organized and took charge of the calculation and design of the company's apparatus and of the research and development work. Since 1902 he has been Professor of Electrical Engineering at Union University, at the same time retaining his connection with the General Electric Company as consulting engineer, organizing and assuming charge of a Consulting Electrical Department in 1911.

In 1902 Harvard University conferred upon him the honorary degree of Master of Arts, and in the following year he was created Doctor of Philosophy by Union University.

Dr. Steinmetz is a fellow of the American Association for the Advancement of Science, a member of the Mathematical Society and of the Physical Society. He is a Past President and member of the American Institute of Electrical Engineers.

He published his "Theory and Calculation of Alternating Current Phenomena" in 1897 (fourth edition, 1908); "Theoretical Elements of Electrical Engineering," 1901 (third edition, 1909); "Theory and Calculation of Transient Electrical Phenomena and Oscillations," 1909 (second edition, 1911); "General Lectures on Electrical Engineering," 1908 (third edition, 1909); "Radiation, Light, and Illumination," 1909 (second edition, 1911); "Engineering Mathematics," 1910. These works are standard text-books in electrical engineering, as well as books of reference to the practical engineer.

He is the author of numerous papers on scientific and electrical subjects, most of which have been published in the "Transactions of the American Institute of Electrical Engineers." He read a paper on "The Physiology of Light" before the Engineers' Club of Philadelphia in 1910, and another on "Some Unexplored Fields in Electrical Engineering" before The Franklin Institute in March, 1911. He contributed an article on "Electric Transients" to the JOURNAL OF THE FRANKLIN INSTITUTE in July, 1911.

Dr. Steinmetz has done much constructive work in the electrical art, having made many important improvements in alternating current motors, generators, converters, regulators, lighting, and the like.

ISHAM RANDOLPH, D.Eng.

DR. ISHAM RANDOLPH was born at New Market, Clark County, Virginia, in 1848. His education, both general and technical, was acquired in the school of experience.

He entered the service of the Baltimore & Ohio Railroad in 1868, going to the Lehigh Valley Railroad three years later.

In March, 1872, Dr. Randolph re-entered the service of the Baltimore & Ohio Railroad and later was resident engineer for a part of its western system. From 1876 to 1885, he had an extensive experience in the building of railroads, railroad terminals, and freight houses in the western section of the country.

In this latter year he opened an office for general engineering work in Chicago. In 1886 he was employed by the Illinois Central Railroad in the location and building of the Chicago, Madison & Northern Railroad and the Freeport & Dodgeville line as chief engineer. In 1888 he resumed the general practice of engineering in the city of Chicago, and was employed as engineer on various projects and later as consulting engineer for the Union Stock Yards and Transit Company and the Baltimore & Ohio Railroad Company.

On July 7, 1893, he was elected chief engineer of the Sanitary District of Chicago, and he served in this capacity for fourteen years, during the entire period of construction of the Chicago Sanitary and Ship Canal, a project costing some sixty millions of dollars. He retired as chief engineer in 1907, and has since served the Sanitary District as consulting engineer.

He was appointed by President Roosevelt on the Board of Consulting Engineers for the Panama Canal, and was one of the five members of the board whose minority report was accepted by the President and Secretary of War, approved by the Panama Commission, adopted by Congress, and the canal is now being constructed in accordance with its recommendations.

In 1908 President Roosevelt invited him to be one of the six engineers whom he wished to have accompany President-elect Taft to Panama to consider "whether or not there is any reason to change the plans upon which we are working." This Board of Engineers submitted its report to the President on Tuesday, February 16, 1909, unanimously upholding the plans for the lock canal across the Isthmus.

Dr. Randolph recently served the city of Milwaukee as consulting engineer on its harbor project and prepared comprehensive plans for harbor improvement there.

He was chairman of the Internal Improvement Commission of Illinois, which commission was charged with the duty of planning the deep waterway from Lockport to Utica, for which the State voted an issue of $20,000,000 in bonds. He is a member of the Illinois State Conservation Commission. He is a member of the Harbor Commission of the city of Chicago, and is consulting engineer for important engineering projects in Toronto, Canada, Buffalo, N. Y., and Baltimore, Md., besides other minor projects in various localities. He is a member of the Rivers and Lakes Commission of the State of Illinois.

In 1910 the University of Illinois conferred upon him the degree of Doctor of Engineering.

He is a past president of the Western Society of Engineers and a member of the American Society of Civil Engineers.

EMILE BERLINER.

EMILE BERLINER was born in Hanover, Germany, May 20, 1851. He was educated in the public schools of that city, and in the Samson High School, Wolffenbüttel, graduating from the latter in 1865. Five years later he came to America and, while engaged in a mercantile pursuit, took up the study of the electric transmission of speech. In 1877 he invented the loose-contact telephone transmitter bearing his name, and which brought Bell's great invention of the preceding year within the range of commercial application and practical use. In the same year he effected another great advance in the telephone art by an application of the induction coil to step-up the low-tension variable current through the loose-contact transmitter to a higher tension variable current capable of better overcoming the impedance of long lines. This loose contact has made the telephone the instrument that it is to-day.

In 1878, on the formation of The Bell Telephone Company, Mr. Berliner accepted the position of Chief Inspector of Instruments at its works in Boston, and in that capacity the first twenty thousand transmitters that went into use passed through his hands.

In 1881 Mr. Berliner, retaining his connection with The Bell Telephone Company, as consulting expert, removed to Washington, and besides bringing out a number of other inventions relating to telephony, devoted his attention to the improvement of the talking machine. In 1887 he invented the gramophone, the first talking machine which utilized a record having a groove of even depth and varying direction and in which the record groove not only vibrates the recording stylus but also propels it. This invention was exhibited by Mr. Berliner before The Franklin Institute in 1888 and was subsequently awarded a John Scott Medal by the City of Philadelphia, on the recommendation of the Institute.

The Berliner Gramophone, now known in America as the "Victor" Talking Machine, and throughout the world under various other trade names, has become the basis of a great and growing industry and an important agency of education and culture. Its popularization has been largely due to the system invented by Mr. Berliner for accurately and cheaply duplicating the original records.

Mr. Berliner has latterly extended his inventive efforts into the field of aviation and has given much attention to the possibilities of the Helicopter as a means of artificial flight. In this field he has also made notable progress toward perfecting a multicylinder motor of the internal combustion type, and has succeeded in greatly reducing its weight in proportion to its power. His engine of this type produced in 1907–8, with a capacity of 35 horsepower, weighed but 97 pounds. These were the first revolving

cylinder motors successfully applied in aëronautical work and led the way to the extensive adoption of this type of motors for aëroplanes in Europe.

In addition to his activity as an inventor Mr. Berliner has given largely of his time to the study of the pathology of milk. His campaign of education on this subject led to the Washington Milk Conference of 1907, and his efforts have been fruitful of beneficial results. In this department of hygiene, as well as in his immediate field of research and invention, Mr. Berliner has made numerous contributions to scientific and technical literature.

LETTERS RECEIVED FROM ELLIOTT CRESSON MEDAL RECIPIENTS WHO WERE NOT PRESENT AT THE STATED MEETING IN MAY.

APRIL 26, 1913.

4, Carlton Gardens,
PALL MALL, S. W.

DEAR SIR:

I have to-day received the Elliott Cresson Medal with its highly flattering inscription.

I beg you to communicate to the Institute my high appreciation of this compliment.

I am, respectfully,

RAYLEIGH.

DR. R. B. OWENS,
FRANKLIN INSTITUTE,
PHILADELPHIA, U. S. A.

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19 CHESTER TERRACE,
REGENT'S PARK, N. W.,
28th April, 1913.

MY DEAR SIR:

I received an official and also a personal letter from Mr. Bryce, saying that he had been commissioned to transmit to me the Elliott Cresson Medal, and two days later I received the medal and the diploma.

It is with feelings of much gratification that I receive this medal; to be associated with such distinguished recipients is a great honour; and to find that my work receives recognition from such a well-known body as The Franklin Institute conveys much pleasure.

May I ask you to be so good as to transmit to the members of the Institute and to those of the Committee on Science and Arts my warm thanks for the honour which they have conferred on me.

I am, dear sir, yours very truly,

WILLIAM RAMSAY.

WALTON CLARK, ESQ.,
THE FRANKLIN INSTITUTE,
PHILADELPHIA.

BERLIN N., den 10 Mai, 1913.
Hessische Strasse 2.

To MR. R. B. OWENS,
Secretary of the Franklin-Institut,
Philadelphia.

Hochverehrter Herr:

Ich habe die Ehre, Ihnen mitzuteilen, dass ich gestern durch Vermittlung unserer Regierung die goldene Elliott Cresson Medal erhielt, die das Franklin-Institut mir verliehen hat.

Aus dem beigefügten Diplom und Ihrem werten Brief vom 2 April d. J. ersehe ich, dass die Verleihung auf Vorschlag des Committee on Science and the Arts geschehen ist.

Die Anerkennung meiner wissenschaftlichen Bestrebungen durch Ihr angesehenes Institut, welches den Namen eines der grössten Naturforscher und Staatsmänner trägt, betrachte ich als eine ganz besondere Auszeichnung, and ich bitte Sie, meinen warmen Dank dafür dem Herrn Präsidenten and dem wissenschaftlichen Komitee, das mich vorgeschlagen hat, übermitteln zu wollen.

Mit vorzüglicher Hochachtung, Ihr ergebener,

EMIL FISCHER.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the June Stated Meeting.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 4, 1913.

MR. J. A. P. CRISFIELD *in the Chair.*

The following report was presented for final action:

No. 2526.—C. Francis Jenkins's Motion Picture Apparatus. Scott Award recommended. Adopted.

The following were recommended for examination and accepted:

No. 2542.—Batdorf Coin-Handling System.
No. 2543.—The Draeger Oxygen Company's Pulmotor.
No. 2544.—Kinkead Shaft-Leveling Machine.

Other business included adoption of report of Subcommittee on Literature for 1912.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

(*Stated Meeting of the Board of Managers, June* 11, 1913.)

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MR. F. HEDLEY JOBBINS, Aurora, Ill.
MR. A. KLIPSTEIN, 644-654 Greenwich Street, New York, N. Y.
MR. H. J. KREBS, President, The Krebs Pigment and Chemical Company, Newport, Del.
PROF. V. LENHER, The University of Wisconsin, Department of Chemistry, Madison, Wis.
PROF. CHARLES E. LUCKE, 117th Street and Broadway, New York, N. Y.
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MR. EUGENE MERZ, Box 216, Newark, N. J.
MR. HERMAN A. METZ, 122 Hudson Street, New York, N. Y.
MR. FRED. J. MILLER, 293 Broadway, New York, N. Y.
PROF. EDMOND O'NEILL, University of California, College of Chemistry, Berkeley, Cal.
PROF. S. W. PARR, University of Illinois, Urbana, Ill.
DR. ISHAM RANDOLPH, 826 First National Bank Building, Chicago, Ill.
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PROF. ALEXANDER SMITH, Columbia University, Department of Chemistry, New York, N. Y.
MR. A. B. STITZER, 3744 North Carlisle Street, Philadelphia, Pa.
MR. I. F. STONE, National Aniline and Chemical Company, 100 William Street, New York, N. Y.
MR. ORIN C. STOUT, Ellwood City, Pa.
PROF. H. P. TALBOT, Massachusetts Institute of Technology, Department of Chemistry and Chemical Engineering, Boston, Mass.
DR. JOHN E. TEEPLE, 50 East Forty-first Street, New York, N. Y.
MR. JOHN L. TUFTS, P. O. Box 22, Winchester, Mass.
MR. HERBERT A. WAGNER, Vice-President, Consolidated Gas, Electric Light and Power Company, Lexington and Liberty Streets, Baltimore, Md.

Changes of Address.

MR. JOHN W. BRASSINGTON, 902 Van Buren Street, Wilmington, Del.
REAR-ADMIRAL JOSEPH B. MURDOCK, U. S. N., Danbury, N. H.
MR. J. STEPH. VAN DER LINGEN, Stapfer Strasse 23, Zurich, Switzerland.

NECROLOGY.

Adolphus Bonzano was born in 1830 at Ehingen, Germany, and was educated in the gymnasia of Ehingen, Dinsdorf, and Stuttgart. While he was yet a boy his father emigrated to Texas.

Mr. Bonzano came to Philadelphia in 1850, and after two years went to Springfield, Mass., where he entered the Reynolds Machine Works, becoming superintendent at the completion of his apprenticeship. He was employed in the mechanical departments of various machine works and railroad shops for a few years, and in 1865 had charge of the construction of the Detroit Bridge and Iron Works. In 1868 he went to Phœnixville and, with the late Thomas C. Clarke and others, organized the Phœnix Bridge Company, of which he was president and chief engineer until 1893. During the next five years he was associated with Mr. Clarke in New York as a consulting engineer, after which he devoted his energies to his inventions of railroad and other engineering appliances.

Mr. Bonzano was elected to membership of the Institute in 1900.

John W. Ridpath was born in Upper Onslow, Novia Scotia, in 1840. At an early age he removed to Pittsburgh, Pa., and later to Jenkintown, Pa., where he resided until his death, on May 8th.

He was for several years engaged in business pursuits, becoming a druggist in 1870. Since 1885 he had served in several local public offices, and was for five years a Justice of the Peace. He was also connected with several turnpike road companies, and was superintendent of the local turnpikes under the Philadelphia Rapid Transit Company.

Mr. Ridpath was a noted local historian, and many of his articles appeared in various magazines. He was also much interested in photography and microscopy.

He was connected with the following societies: Jenkinstown Lyceum Association, Abington Library Society, American Good Roads Association, Bucks County Historical Society, National Geographical Society, The Philadelphia College of Pharmacy, The Pennsylvania Pharmaceutical Association, and many fraternal and secret organizations.

His membership in the Institute began in 1881; he took an active interest in its work, both by lecturing on several occasions before its Photographic Section and also as a member of its Committee on Science and the Arts since 1891.

LIBRARY NOTES.

Purchases.

ABNEY, W. DE W.— Researches in Colour Vision. 1913.
BOGÆRT, ED. W.—L'Effet gyrostatique et ses applications. 1912.
CANTELL, M. T.—Reinforced Concrete Construction. 1912.
CHRISTIE, W. W.—Water: its purification and use in the industries. 1912.
CODD, M. A.—Electrical Ignition for Internal Combustion Engines. 1911.
FISCHER, A.—Elektroanalytische Schnellmethoden. 1908.

Frodiar Iron and Steel Company Publication.—Handbook for Iron Founders. 1910.

GRUENWALD, J.—The Technology of Iron Enamelling and Tinning. 1912.

HERRMANN, G.—The Graphical Statics of Mechanism. 1904.

HURST, H. E. and R. T. LATTEY.—A Text-book of Physics. 3 volumes. 1912.

LE MAITRE, W.—Natural Stability and the Parachute Principle in Aëroplanes. 1911.

LEVY, D. M.—Modern Copper Smelting. 1912.

LUNGE, G.—The Manufacture of Sulphuric Acid and Alkali. Vol. 1. 4th edition. 3 volumes. 1913.

MACLAURIN, R. C.—The Theory of Light. Part 1. 1908.

MASTIN, JOHN.—The Chemistry, Properties, and Test of Precious Stones. 1911.

RAPER, C. L.—Railway Transportation. 1912.

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BOOK NOTICES.

THE EXAMINATION OF WATERS AND WATER SUPPLIES. John C. Thresh, D. Sc., 2d edition, 8vo., 624 pages and index, illustrated, Philadelphia, P. Blakiston's Son & Co. $5.

Dr. Thresh is so well known in this field that we can be sure that the work before us will be comprehensive and valuable. The subject-matter is divided into three parts: Examination of the sources of water, interpretation of analytic methods and analytic processes. Many interesting examples are detailed of the problems confronting the sanitary engineer in dealing with the increased demand and increased pollution of water in highly-civilized com-

munities. In connection with the microscopic examination of water sediments, many of the common vegetable and animal forms encountered in such work are figured, the degree of magnification being generally given. This is an important point, that should never be neglected in representing microscopic fields.

Notwithstanding Dr. Thresh's familiarity with the literature of the subject, and, as noted by a remark in the book, actual observation of the work in American laboratories, his own point of view is almost exclusively English, and in some respects quite old-fashioned, although it is not intended by this term to indicate that the methods are not trustworthy. Still, the reviewer cannot see any excuse for such a term as "permanganate of potash," which occurs several times in the volume. Nor does there appear to be any scientific consistency in the spellings "grammes" and "milligrams."

In the determination of nitrates, Dr. Thresh uses the copper-zinc couple, and specially condemns the phenolsulphonic acid method. In view of the large amount of investigation recently given to this method, especially by American chemists, it is to be regretted that the author did not give in some detail the routine he followed. From the formula he gives for preparing the reagent, it seems evident that he has not made any comparison between the copper-zinc couple method and that with phenoldisulphonic acid, which is the reagent now used largely by American chemists. It is now known that the mixture of sulphonic acids obtained in the original process of preparing the reagent is not satisfactory, and it is not likely that any careful worker uses this form. Gill took up the matter a number of years ago, and made an important step forward in suggesting the heating of the reagent for six hours in boiling water. A few years ago, Messrs. Chamot, Pratt and Redfield still more extensively investigated the method and gave an improved formula for the preparation of the reagent (*J. Amer. Chem. Soc.*, 1911, 366). It seems to the reviewer that before a simple and rapid process is condemned it should be tried out in its most improved form.

The time is, probably, rapidly passing when either chemical or bacteriologic tests of isolated samples of surface and ordinary subsoil water will be required. The practical issues are now largely questions of engineering, and, so far as surface water is concerned, it has long been known that in an unfiltered condition it is always unsafe for general use, and we need no specific biologic or abiologic datum to tell us this.

HENRY LEFFMANN.

GENERAL INDEX TO THE CHEMICAL NEWS, Vols. 1 to 100. Chemical News Office, London. 712 pages, 26 x 18 cm. Price, $10.

This index covers the first one hundred volumes of the journal in question in what appears to be a very thorough way. Each page contains three columns of small but clear type. The articles are listed both under author and subject, but the two departments are not separated. The index seems very complete and forms an interesting survey of the period covered by it. It should be of great value to chemists who possess files of the *Chemical News*.

ROBERT H. BRADBURY.

THE INDUSTRIAL ARTS INDEX. A cumulative index to engineering and trade periodicals. Published by the H. W. Wilson Company, Minneapolis, Minn.

The first issue of this publication, dated February, 1913, contains a list of the articles which appeared in January and February in forty-three leading periodicals in the English language devoted to the various branches of engineering, chemistry, mining and metallurgy, and other industrial fields.

The second number indexes, in one alphabet, all articles published during the four months, January to April, in nearly fifty magazines.

The index is arranged on the dictionary plan and contains in addition to the author entry as many subject entries as the contents demand. Cross references point the way to material on allied subjects. Volume number, page, and date are given for each article, and note is also made when illustrations accompany it.

The index will appear five times in each year, each number will be fully cumulated to date of issue, and the December issue will be the annual cumulation. It is the intention to increase the number of magazines to be indexed from time to time, and by the end of the current year the number will reach 80, increasing ultimately to about one hundred.

No flat subscription rate has been made; instead, a sliding scale of prices will apply, the rate to each subscriber is to be determined by the number of periodicals subscribed for which are indexed. Further details may be had from the publishers.

PUBLICATIONS RECEIVED.

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Utilization of Peat. F. M. PERKIN. (*Chem. Trade Journ.,* lii, 89.)—This article considers the utilization of peat as a high-grade fuel under certain conditions; as a source of charcoal, with the formation of gas of high calorific value, and ammonia and tar as by-products; and further as a source of power gas.

The Oil Situation in Northern Alberta. WM. FISHER. (*Petroleum Rev.,* xxvii, 323.)—Inconceivably large quantities of gas have been discovered. One well has been burning with terrific force for 15 years. The gas pressure is 795 pounds per square inch, and the flow is 68,000,000 cubic feet per 24 hours. Enormous deposits of tar sands have been found.

The First Attempt at the Synthesis of Nitric Acid. C. MATIGNON. (*Rev. Scientifique,* No. 12, 360.)—Madame Louise J. P. B. Lefebvre, of Paris, took out an English patent, dated April 26, 1859, under the title "Improvements in the manufacture of nitric acid and its application to the production of artificial nitrates and nitrites." Briefly, one flask is inverted over another flask. In the upper flask two poles of a battery are fixed from which an electric spark is flashed, which decomposes the air in the flask. Air is passed in a continuous current. The nitrogen oxides formed are absorbed by water or an alkaline solution in the lower flask; this water is decomposed by the electric current and so furnishes oxygen to combine with the atmospheric nitrogen.

CURRENT TOPICS.

Fixation of Units by Legislation. R. DE BAILLEHACHE. (*Rev. Gén. des Sciences,* Jan. 15, 1913.)—The French Minister of Commerce and Industry has asked the various commercial, industrial, and scientific communities whether this would not be an opportune time to fix by legislation new units, such as the units of force, heat, light, and electricity, and the author reviews the whole question, mainly from the national standpoint and in anticipation of forthcoming legislation. In addition to the usual units of length, mass, etc., the term *cop* is proposed for the absolute unit of force on the decimal metric system. *Unit of force.*—The cop (an abbreviation of Copernicus) is that force which, acting on a mass of one kilogramme, gives it an acceleration of one metre per second. In published works the additional unit of force, the hectogramme, could be used. A force of one hectogramme = 0.980665 cop. Conversely, one cop = 1.01972 hectogramme (mass). *Unit of work.*—While the absolute unit of work or energy is the joule, in transactions the additional unit, the hectogramme-metre could be used (one hectogramme-metre = 0.980665 joule). *Unit of power.*—The absolute unit is the watt: this is the power generated by the displacement of a force of one cop at a speed of one metre per second. As additional unit the poncelet could be used (one poncelet = one kilowatt approximately, or exactly 0.980665 kilowatt, and is $^4/_3$ of the older *cheval-vapeur* of 75 kilogramme-metres). *Unit of pressure.*—The absolute unit is the decabarye [decabar] (or tor, an abbreviation of Torricelli), and is the pressure exerted by the force of one cop uniformly distributed on a surface of one metre-square. The sub-multiple, $^1/_{10}$, of this is called the *barye* (= the pressure of a column of mercury of 750.05 millimetres in height at 0° C.). In industrial work the "atmosphere" to be retained (one atmo = the weight of a column of mercury 735.5 millimetres in height at 0° C. = 98066.5 decabaryes). The normal standard atmospheric pressure = 101321.1 decabaryes, or about 1,000,000 *baryes.* Then follows a discussion of the definitions of the various units, and concludes with the hope that future legislation will recognize the beauty and harmony of the M. K. S. (metre, kilogramme, second) system.

Effect of Temperature and Vibration on Drawn Tungsten Filaments. O. SCARPA. (*Atti dell' Assoc. Elettr. Ital.,* xvi, 638.)—Drawn tungsten filaments are found to have an entirely different structure from those prepared by reduction of the oxide, the former

being fibrous, while the latter are granular. Examination of the filaments after burning in lamps for 500 hours with either a continuous current, producing a temperature of about 1900° C., or an alternating current of 42 cycles, shows that in both cases the metal is transformed into the micro-crystalline condition, just as has been previously shown to occur with the old filaments produced from the oxide. Drawn tungsten filaments should, therefore, be much more durable than drawn tantalum filaments, which form larger crystals under the combined action of temperature and vibration.

Explosion of Hydrogen Cylinders. LELARGE. (*Comptes Rendus,* clv, 914.)—Two men were killed in 1911 while measuring the gas pressure of hydrogen in a steel cylinder. Apparently the explosion was due to the rapid compression of the air in the tube connecting the cylinder to the gauge. In experiments conducted in the Laboratoire d'Aeronautique Militaire the cylinders were placed inside a strong steel cage built up of hoops and tie-rods, and a pipe packed with disks was interposed between the cylinder and the gauge to take up any heat generated by a minor gas combustion within the gauge. The gas pressure was first determined with the safety tube in position; the gas was then analyzed, and the pressure re-determined without the safety device; explosion occurred when the hydrogen was sufficiently impure. In practice all cul-de-sac connections should be avoided or be arranged like a safety tube, and the density of the gas should be measured before taking the pressure. Great care is needed in dealing with heavy hydrogen, probably containing air or oxygen, especially if electrolytic.

Titanic Acid in Underglaze Colors. A. BERGE. (*Sprechsaal,* xlvi, 206.)—The color produced by a stain depends, to some extent, on the reaction of the other constituents on the chief coloring oxide. Cobalt, for example, gives a deep dark-blue with silica and a sky-blue with alumina. The tints are further affected by zinc oxide, phosphoric acid, etc. The component oxides of a stain may be intimately mixed by fine grinding, by precipitation of the hydroxides, by melting together of sulphates in their water of crystallization, or by Pukall's "suction" method, in which soluble salts of coloring oxides are absorbed by kaolin, etc., and then calcined and ground. Titanic acid is recommended as a carrier for other coloring oxides. Trials were fired in majolica, stoneware, and porcelain kilns, of rutile thus used with the oxides of uranium, cobalt, iron, nickel, copper, manganese, chromium, molybdenum and tungsten. A wide range of colors was obtained from yellow to blue-black. The best results for underglaze, when using titanic acid alone, were obtained at cone 7–9 for olive-green, brown, and yellow tints.

Edeleanu's Process of Refining Petroleum Oil. C. ENGLER and L. UBBELOHDE. (*Z. Angew. Chem.*, xxvi, 177.)—This method was tested both in the laboratory and on the industrial scale. In the industrial tests the petroleum distillate to be refined was first dried by a fused mass of one part of calcium chloride and four parts sodium chloride, then pumped into a cooling chamber, some of its heat being abstracted by passing through pipes in contact with previously chilled refined oil. The liquid sulphur dioxide was chilled in a similar manner and conveyed to another cooling chamber. When both oil and reagent were cooled to about —10° C., the oil was run into a mixing chamber and the requisite quantity of liquid sulphur dioxide (1.3:1) forced to flow in a state of fine division over its surface. In this way the oil became saturated with sulphur dioxide without the need of mechanical agitation. The lower layer consisting of sulphur dioxide extract was drawn off for evaporation, while the upper refined part was drawn to another chamber. The sulphur dioxide was evaporated from both parts by steam coils, and was condensed again and returned to the liquefied gas reservoir. The refined oil then only contained about 0.2 per cent., and the extract about 0.4 per cent., of sulphur dioxide, and this could be easily washed out with water. A plant for treating 62 tons of oil per day could easily be run by three men, and the total cost of refining 100 kilos of petroleum oil amounted to M.0.436 (5 cents per 100 pounds). The refined oil thus obtained invariably had a lower specific gravity than the original distillate, that of the extract being correspondingly higher. The refined portion from crude distillates of every kind was nearly colorless, any faint yellow color being readily removed by a slight refining with 0.5 per cent. of sulphuric acid. This refined oil burned with a strong white flame without smoke, and in these respects was equal to the best lamp oil. The extract, on the other hand, was yellow to brown in color and could not be burned in lamps. Photometric tests also showed that the lamp oil refined by the new process was superior to that refined by the ordinary method, and that it was nearly equal in intensity of light to the best American oils. The extract consisted chiefly of unsaturated hydrocarbons, homologous compounds to benzene, etc., and could be used in the preparation of substitutes for oil of turpentine, and especially for such purposes as oils rich in unsaturated hydrocarbons (*e.g.*, oils from Borneo and Texas) are used. In fact, these extracts would be more suitable than the natural oils mentioned, as solvents for many resins. The constituents boiling above 200° C. could not be used for this purpose, but might be used as lubricants and gas oils, while the tar obtained in the latter process would contain a considerable quantity of the lower aromatic hydrocarbons, which would increase its value under certain conditions.

β-Gold. M. HANRIOT and F. RAOULT. (*Bull. Soc. Chim.*, xiii, 260.)—Finely-divided annealed gold is found to be appreciably attacked by boiling nitric acid; 0.076 gramme of metal is dissolved from 5 grammes of gold by 100 c.c. of monohydrated acid in two hours; and brown gold is still more soluble, 1.54 grammes being dissolved under the same conditions. Brown gold is dissolved more readily than yellow gold by a solution of auric chloride in the presence of hydrochloric acid, giving a solution which on cooling yields a crystalline deposit of metallic gold. A study of the magnetic susceptibilities of the original brown gold, the crystalline gold obtained by solution, and the residual gold leads to the conclusion that from brown gold, which is regarded as a mixture of α- and β-gold, pure β-gold (crystalline gold) may be prepared by treatment with a solution of gold chloride, α-gold being left as a residue.

The Future of Motor Spirit. V. B. LEWES. (*Chem. World*, ii, 111.)—The imports of petrol into Great Britain have increased from 18,000,000 gallons in 1905 to 80,000,000 gallons in 1912, while the world's production of crude oil has only increased from 28,500,000 to 50,000,000 tons. The principal sources of petrol imported in 1912 were the Dutch East Indies and America, which sent 46,000,000 and 16,000,000 gallons respectively. The surplus available for export from America is decreasing, and the excess of demand over supply has raised the price of crude oil at the oil fields. There are methods available for increasing the yield of petrol from crude oil. By compressing the gas which escapes from the oil wells a light spirit is recovered which may be mixed with the fractions of higher boiling-point. The petrol used for motor spirit has a specific gravity of 0.72 or higher, as compared with 0.68 when the supply was greater than the demand. The heavier fractions of crude oil may be converted into light oils by distillation in contact with catalysts such as nickel, or by "cracking." One process consists in spraying "solar oil" (a heavy fraction from American petroleum) with water into long iron retorts packed with iron filings and heated to 600° C. and condensing the vapors obtained fractionally; 100 gallons of "solar oil" yield 39 gallons of petrol, 13 gallons of solvent spirit, and 13 gallons of "varnish." Crude oil cannot be a lasting source of supply of motor spirit. The quantity of motor spirit (benzol, etc.) available from gas works in England at present is only 50,000 gallons per annum, and 8,000,000 gallons of benzol are recovered in coke-oven plants, which only treat 42 per cent. of the coal used for making metallurgical coke. The Scotch shale oil industry yields about 600,000 gallons of motor spirit annually. The motor spirit of the future will probably be alcohol, mixed with about 10 per cent. of benzol.

Electrolytic Theory of the Corrosion of Iron. B. LAMBERT. (*Faraday Socy.*, April 4, 1913.)—Having already shown that water and oxygen are the only essentials to effect the rusting of iron, the author supports the electrolytic theory of corrosion and attributes the formation of rust to combination of the ferrous ions with the hydroxyl ions.

Radioactive Disintegration Products. A. FLECK. (*Chem. Soc. Trans.*, ciii, 381.)—Fleck finds that uranium-X and radio-actinium are chemically similar to, and non-separable from, thorium; mesothorium-2, non-separable from actinium; thorium-B is non-separable from lead; radium-B and actinium-B are very similar to lead, and probably non-separable from it; thorium-C, radium-C, and actinium-C are very closely allied to bismuth, and probably non-separable from it; radium-E is chemically identical with bismuth. Direct measurement of the development of radium-F from radium-E has confirmed the view that there is only one product (radium-E) between radio-lead and polonium.

Solar Energy and its Utilization. ANON. (*Amer. Mach.*, xxxviii, 20, 824.)—James O. Handy gave the following statement before the Engineers' Society of Western Pennsylvania: In the tropics, assuming the solar constant at 1800 calories per hour per square metre, it is easily seen that the heat per square kilometre will be equal to that produced by the combustion of 1000 tons of coal. A surface of only 10,000 square kilometres receives in a year, calculating a day of only 6 hours, a quantity of heat corresponding to that produced by burning 3,500,000,000 tons of coal, or more than three times the annual production of coal. The Desert of Sahara, with its area of 6,000,000 square kilometres, receives daily solar energy equivalent to 6,000,000,000 tons of coal. It is estimated that as a result of the sun's rays and the presence of moisture and carbon dioxide, etc., in the earth's crust and in the air the earth produces yearly 32,000,000,000 tons of vegetable matter, which, when burned, would correspond to 18,000,000 tons of coal. Thus the exhaustion of coal can be prepared for by studying which types of vegetation produce woody fibre most rapidly, and we can use intensive and extensive methods of cultivating them for fuel, and afterward convert this fuel into energy in the most economic way. There is reason for hope, however, that we may be able to do more than to improve agricultural methods of producing fuel, if we take advantage of the fact that many chemical changes are produced by the action of the sun's rays, and that some of these now known, or which may be discovered, may be the basis of a method of converting the sun's energy in dry, tropical countries quite directly into a form which may be transmitted to habitable countries where it may be used.

Aluminum Transmission Lines. ANON. (*Eng.*, xcv, No. 2455, 86.)—The British Aluminum Company, Limited, of 109 Queen Victoria Street, London, E. C., has published a pamphlet dealing in considerable detail with the use of aluminum for overhead electric transmission lines. It states the general conditions, determines the design of transmission lines, gives a large amount of technical information for both copper and aluminum, from the transmission line point of view, and makes out a strong case for aluminum. This information covers comparative figures for conductivity, weight, tensile strength, temperature resistance effect, and expansion coefficients for the two materials. Questions of deflection and stress, jointing, the losses on lines, etc., are also dealt with, and the official standards for overhead line construction of various countries are given. This work should be consulted by all concerned with actual or projected overhead transmission work.

Weight Efficiency of Electric Motors and Prime Movers. W. B. HIRD. (*Inst. Elect. Engin. Journ.*, xlix, 620.)—An interesting paper which covers these subjects: The comparison of weight efficiencies of electric motors and of different types of prime movers; the choice of the unit for comparison; the general law connecting weight and output adopted as a working hypothesis; graphs embodying the results of investigations on steam engines, steam turbines, gas engines, oil engines, petrol engines, water turbines, and electric motors. The original paper will repay the perusal of those interested, especially the numerous curves and diagrams, and the table showing the "horsepower per revolution per ton of material" for the various kinds of prime movers.

Solubility of Radium Emanation in Water. M. KOFLER. (*Monatsh. Chem.*, xxxiv, 389.)—The values for the solubility of the radium emanation in distilled water at various temperatures (*i.e.*, the equilibrium ratio of the emanation concentration in the liquid phase to that in the gaseous phase) are as follows:

Temp.	Solubility	Temp.	Solubility
0.5° C.	0.526	60° C.	0.127
17.5° C.	0.283	74° C.	0.112
35.0° C.	0.185	79° C.	0.111
41.0° C.	0.161	82° C.	0.111
51.0° C.	0.138	91° C.	0.108

The temperature coefficient is of the same order of magnitude as for other gases, decreasing with increase of temperature, and above 70° C. the solubility is constant within the limits of experimental error; but no minimum is shown on the solubility curve, as is the case with helium and hydrogen, although such minima might be expected with gases generally, from theoretical considerations.

Temperatures of the Decomposition of Carbonates. K. FRIEDRICH. (*Centralbl. f. Mineralogie,* 1912, 616, 651, 684.)—A number of pure mineral carbonates in the form of fine powder were submitted to the heating action of an electric current, which was regulated so as to raise each specimen to a temperature of 1130° C. within an hour. The periods of time during which the heating continued, and the corresponding temperatures, were plotted on curves, which indicated for each substance the point when absorption of heat began and the point at which it reached a maximum. The first indicated the temperature of incipient dissociation (*a*) and the other the temperature of maximum decomposition (*b*), in all cases except those of strontium and barium carbonates, which were found to undergo molecular transformations at temperatures of about 300° C. below their temperature of decomposition. The values of (*a*) and (*b*) for different minerals are:

		a	*b*
Cerussite ($PbCO_3$)	about	315° C.	335° C.
Smithsonite ($ZnCO_3$)	about	395° C.	440° C.
Siderite ($FeCO_3$)	about	400° C (?).	460° C.–500° C.
Basic lead carbonate		430° C.	460° C.
Rhodocrosite ($MnCO_3$)		510° C. (?)–525° C.	550° C.–570° C.
Magnesite ($MgCO_3$)		570° C.	600° C.
Calcspar and Arragonite ($CaCO_3$)		895° C.	910° C.
Strontianite ($SrCO_3$)	over	1130° C.	
Witherite ($BaCO_3$)	over	1100° C.	

Catalytic Action of Mercury in Nitrations. R. WOLFFENSTEIN and O. BÖTERS. (*Ber.,* xlvi, 586.)—When concentrated nitric acid, or a mixture of nitric and sulphuric acids, acts on benzene in presence of mercuric nitrate, nitro-benzene only is yielded; while if nitric acid of lower concentration is used it acts in the first place as an oxidizing agent, and as a final product yields nitrophenols. A mixture of 100 grammes benzene, 800 grammes nitric acid of specific gravity 1.31, and 15 grammes of mercuric nitrate was heated on the water-bath under a reflux condenser with vigorous stirring. Nitrous gases were evolved, and the residue after cooling yielded a crystalline mass of 1.2.4-dinitrophenol and picric acid,—*i.e.,* the same products that are obtained by the direct nitration of phenol. Benzene derivatives react in an analogous manner. Oxides of nitrogen or nitrous acid may be used in place of nitric acid. 1.2.4-dinitrophenol in an almost pure state may be prepared directly from benzene by either of the following methods: (1) 120 grammes of benzene are mixed with 20 grammes of mercuric nitrate and the mixture treated with 270 grammes of nitrogen tetroxide and allowed to stand for some days at ordinary temperature. (2) 120 grammes of benzene are treated with 10 grammes of mercuric nitrate and 500 grammes of 50 per cent. nitric acid, 50 grammes of nitric oxide are added, and the mixture is stirred and heated to 50° C.

Illuminating Engineering Society.—The annual convention of the society will be held in Pittsburgh, Pa., beginning September 22, 1913.

An interesting programme is being prepared, which will include the usual number of social events, excursion trips, and visits to industrial establishments in or near Pittsburgh.

The Mode of Combustion of Carbon. T. F. E. RHEAD and R. V. WHEELER. (*Chem. Soc. Proc.*, xxix, 51.)—The authors have shown that carbon dioxide and carbon monoxide are produced together when carbon is burned, and now they give experiments to show how this simultaneous production of the two oxides occurs. Carbon, at all temperatures up to 900° C. and probably above that temperature, has the power of pertinaciously retaining oxygen. This oxygen cannot be removed by exhaustion alone, but only by increasing the temperature of the carbon during exhaustion. When quickly released in this manner, it does not appear as oxygen, but as carbon dioxide and monoxide. The proportions of these two oxides when completely removed depend on the temperature at which the carbon has been heated during oxygen fixation. This "fixation" cannot be accounted for by any physical explanation; in all probability it is the outcome of a physico-chemical attraction between carbon and oxygen: physical, inasmuch as it seems hardly possible to assign any definite molecular formula to the complex formed, which indeed exhibits progressive variation in composition; chemical, in that no isolation of the complex can be effected by physical means. When the complex is decomposed by heat, carbon dioxide and monoxide are produced. At a given temperature of decomposition these oxides make their appearance in a given ratio. Further, when a rapid stream of air at a given temperature is passed over carbon (which has been previously saturated with oxygen at that temperature), carbon dioxide and monoxide appear in the products of combustion in nearly the same ratio as they do in the products of decomposition of the complex at that temperature. It is therefore suggested that the first product of combustion of carbon is a loosely-formed physico-chemical complex which can be regarded as an unmistakable compound of carbon and oxygen of an, at present, unknown formula, CxOy. It is probable that no definite formula can be assigned to this complex.

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